BBC

2022'S MOST MIND-BLOWING IMAGES

Science Focus

Understand
HOW HORMONES WORK

The treasure
BENEATH THE MELTING GLACIERS

Should you take
A GENETIC HEALTH TEST?

HEALTH TARGETS DO THEY WORK?

Five-a-day, 10,000 steps, 2,000 calories...
How recommended daily allowances stand up to modern science

SF
SCIENCEFOCUS.COM
ISSUE #386 NEW YEAR 2023
UK £5.50 US $11.50 CAN $13.99 AUS
$13.50 NZ $19.99

IN THIS ISSUE

Michael Mosley
Eccentric exercise: how to make your workout more efficient

Physics
The mysteries of matter's most basic building block

Carnivore diet
The pros and cons of 'eating like our ancestors'

mpb.com

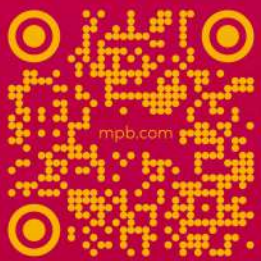
Trustpilot

"I'll keep this short: **their system is simple, the pickup is guaranteed and a no-quibble payment** swiftly follows. You get exactly what you would from eBay, but without the hassle."

MPB customer review

Turn your spare kit into spare cash.
Sell to MPB.

Scan the QR code
and get a free
quote in seconds



Buy•Sell•Trade
Create

FROM THE EDITOR

Five-a-day, eight hours of sleep, 2,500 calories… recommended daily allowances or amounts make me anxious. It's my fault, I rarely meet them. It's not just these guidelines either, I don't think that there are any 'public health commandments' that I follow. Exercise for 150 minutes every week? Nope. Two litres of water a day? Never. No more than 14 units of alcohol in a week? Not this month.

Evidently, I'm going to fall to pieces any minute now. Or maybe not. These guidelines, many of them ingrained in the public consciousness, though well-intentioned, are clearly not the final word on how to lead a healthy life. But how well do they stand up against our current thinking? At a time of year when we collectively emerge from a turkey-fuelled stupor, we look at what kind of health targets you really ought to be setting yourself and what health 'truths' aren't set in stone. Turn to p66 to find out more.

As it's that time of year, we've also taken a moment to look back at the images that blew our minds in 2022. Clearly, the James Webb Space Telescope upstaged everyone in this regard this year, but there are some absolutely staggering photos that I bet you've never seen before (including my favourite, a robot made out of a dead spider!). Head over to p6 to see them all.

See you in the New Year!

Daniel Bennett, Editor

WANT MORE? FOLLOW **SCIENCEFOCUS** ON FACEBOOK TWITTER PINTEREST INSTAGRAM

COVER: JOE WALDRON THIS PAGE: ALAMY, GETTY IMAGES, PAUL WILKINSON/ ROYAL INSTITUTION, DANIEL BRIGHT

ON THE BBC THIS MONTH...

The Royal Institution Christmas Lectures
Okay, so we told you about this last month. But we're still super excited to see Prof Dame Sue Black take centre stage at the Royal Institution to share the secrets of forensic science. And if you're too busy thrashing your family at *Monopoly* to watch, you can always tune in on iPlayer later.
BBC Four
26, 27 and 28 December, 8pm
Also available on iPlayer

Sliced Bread
This might be our new favourite radio show. In *Sliced Bread*, Greg Foot challenges the latest fads and trends in the world of science, health and technology to find out whether the bold claims made by advertisers really stand up.
BBC Radio 4
Thursdays, 12:32pm
Also available on BBC Sounds

The War Of The Worlds
It's 125 years since the publication of HG Wells's science fiction story, which was later made famous by the broadcast by Orson Welles that caused panic among its listeners. Well if you want to recreate that experience, tune in bright and early to Radio 4 Extra in the New Year.
BBC Radio 4 Extra
Starts 2 January, 6:30am
Also available on BBC Sounds

Can animals be allergic to humans? →p75

CONTRIBUTORS

SIR PETER DONNELLY
Peter, a professor of statistical science, gave us the lowdown on the new wave of genetic health tests that tell you your risk of developing certain diseases in the future. →p32

DR WENDY HALL
Social media is awash with health gurus who believe that a meat-based diet is best. We asked nutritional scientist Wendy to examine the claims of the carnivore diet. →p42

DR MICHAEL MOSLEY
Are you exercising eccentrically? Michael, who presents BBC Radio 4's *Just One Thing*, explains why you should pick up a top hat and invest in a unicycle… only kidding. Turn to his feature to find out more. →p58

JHENI OSMAN
For BBC Radio 4's *Costing The Earth*, science writer and editor Jheni scaled the Alps to learn more about the artefacts emerging from the melting glaciers and the race to preserve them. →p60

CONTACT US

Advertising
David.DSouza@ourmedia.co.uk
0117 300 8110
Letters for publication
reply@sciencefocus.com
Editorial enquiries
editorialenquiries@sciencefocus.com
0117 300 8755
Subscriptions
buysubscriptions.com/contactus
03330 162 113*
Other contacts
sciencefocus.com/contact

*UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am-5pm. If calling from overseas, please call +44 1604 973721. *BBC Science Focus* (ISSN 0966-4270) (USPS 015-160) is published 14 times a year (monthly with a Summer issue in July and a New Year issue in December) by Our Media Company, Bristol, Eagle House, Bristol, BS1 4ST. Distributed in the US by NPS Media Group, 2 Enterprise Drive, Suite 420, Shelton, CT 06484. Periodicals postage paid at Shelton, CT and additional mailing offices. POSTMASTER: Send address changes to *BBC Science Focus*, PO Box 37495, Boone, IA 50037-0495.

CONTENTS

REGULARS

20 CONVERSATION
See what's been in our inbox this month.

23 DISCOVERIES
Artificial sweeteners found in sugar-free foods can kill antibiotic-resistant bacteria; AI can predict the risk of heart disease by analysing a single chest X-ray; bats grunt like death metal singers to communicate; irritable bowel syndrome may be caused by body's inability to deal with gravity; there are no signs of aliens on Venus; can genetic tests reliably predict disease?

34 DR KATIE MACK
A proton should be one of the simplest particles in physics, yet its weird properties send scientists down a rabbit hole of complexity.

36 DR KATE DARLING
We can now have a 'real' conversation with an AI, but who is benefiting from this tête-à-tête?

38 DR JULIA SHAW
Eco-anxiety is on the rise, but we can harness it to help make the world a better place.

42 REALITY CHECK
The science behind the headlines. Can all-meat diets keep us healthy? Is it possible to overcome social anxiety? Are food aversions learned or genetic?

49 INNOVATIONS
The latest tech and gadgets news.

75 Q&A
Our experts answer this month's questions. Can animals be allergic to humans? Why do I feel better after I've cracked my neck? Do we really need to accept cookies on a website? Why are fish fish-shaped?

82 EXPLAINER
Everything you wanted to know about your body's messengers, the hormones.

88 CROSSWORD
Give your brain a workout!

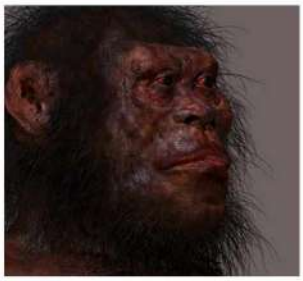
88 NEXT MONTH
A sneak peek at the next issue of *BBC Science Focus*.

90 POPCORN SCIENCE
In *M3GAN*, a robot doll can communicate, dance and...kill. So how close are we to artificially intelligent kids' toys with a mind of their own?

56 SUBSCRIBE TODAY!

Three issues for £5 when you subscribe to *BBC Science Focus*!

23 DISCOVERIES

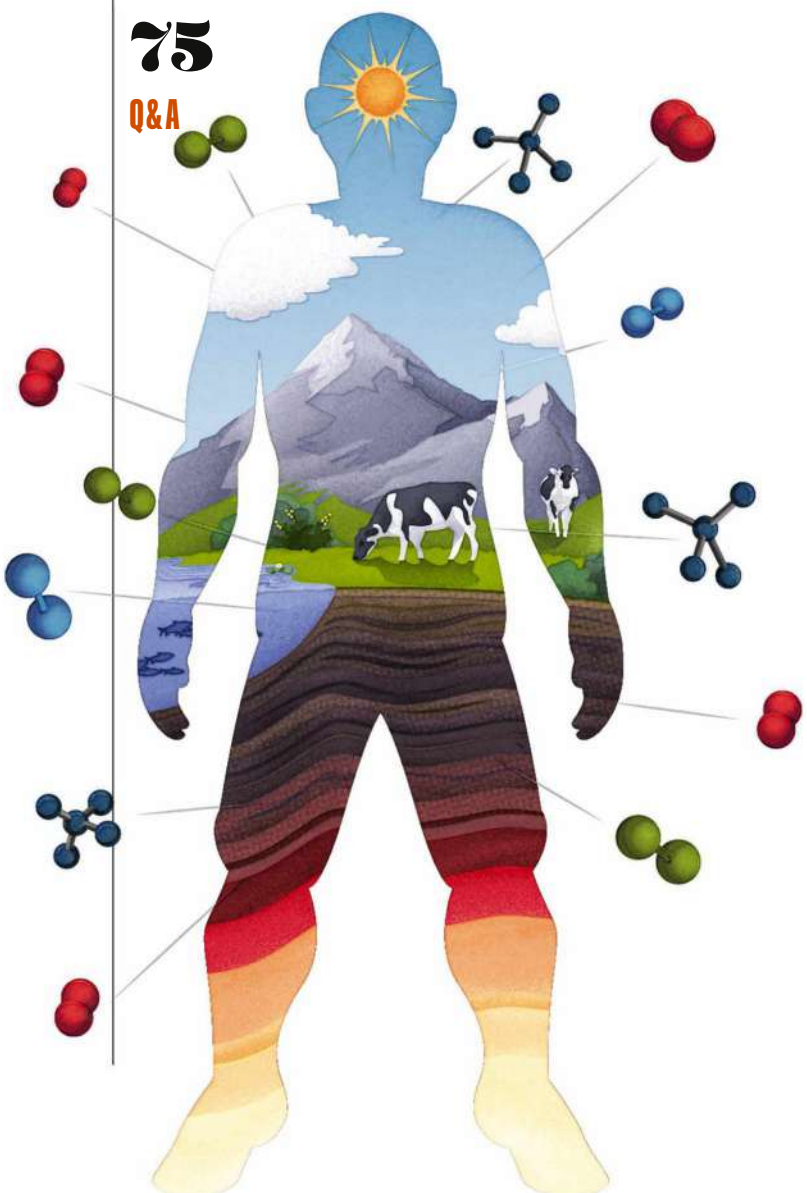


Homo naledi, an extinct hominid, may also have harnessed the ability to control fire.

42 REALITY CHECK

Can a meat-and-offal-filled diet keep you ripped and healthy, as claimed by the Liver King?

75 Q&A



FEATURES

06 THE BEST SCIENCE IMAGES OF 2022
Our pick of the pics from the past year.

58 THE NEW WORLD OF ECCENTRIC EXERCISE
Forget running up the stairs and climbing hills, it turns out that doing the exact opposite might be better for you, says Dr Michael Mosley.

60 FROZEN IN TIME
As the planet warms, melting ice is revealing ancient objects previously hidden from view. Jheni Osman visits the Swiss Alps to find out more.

66 RECOMMENDED HEALTH TARGETS: DO THEY WORK?
Do we really need to eat five-a-day, drink eight glasses of water, and plod 10,000 steps?

06
THE BEST SCIENCE IMAGES OF 2022

54
IDEAS WE LIKE...
A microphone that'll make it easier to record our podcasts.

66
DR SARAH BERRY

"FOCUS ON HOW HEALTHY A FOOD IS, NOT ON HOW MANY CALORIES IT HAS"

WANT MORE?

Don't forget that *BBC Science Focus* is available on all major digital platforms. We have versions for Android, as well as an iOS app for the iPad and iPhone.

Can't wait until next month to get your fix of science and tech? Our website is packed with news, articles and Q&As to keep your brain satisfied.
sciencefocus.com

INSTANT GENIUS
Our bite-sized masterclass in podcast form. Find it wherever you listen to your podcasts.

LUNCHTIME GENIUS
A DAILY DOSE OF MENTAL REFRESHMENT DELIVERED STRAIGHT TO YOUR INBOX
Sign up to discover the latest news, views and breakthroughs from the *BBC Science Focus* team
www.sciencefocus.com/newsletter

WHEN IT COMES TO PHOTOGRAPHY, THE JAMES WEBB SPACE TELESCOPE STOLE THE SHOW, WITH VISUALS THAT REMINDED US WHAT AN OUTRAGEOUSLY BEAUTIFUL PLACE THE UNIVERSE CAN BE. BUT TO TELL THE TRUTH, OVER THE LAST 12 MONTHS THERE WAS NO SHORTAGE OF MIND-BLOWING IMAGES THAT CHANGED OUR PERSPECTIVES. HERE'S OUR SELECTION OF THE BEST, AND WHAT THEY TAUGHT US...

by HAYLEY BENNETT

THE BEST SCIENCE IMAGES OF 2022

Window on the Universe

LONDON, UK
12 JULY

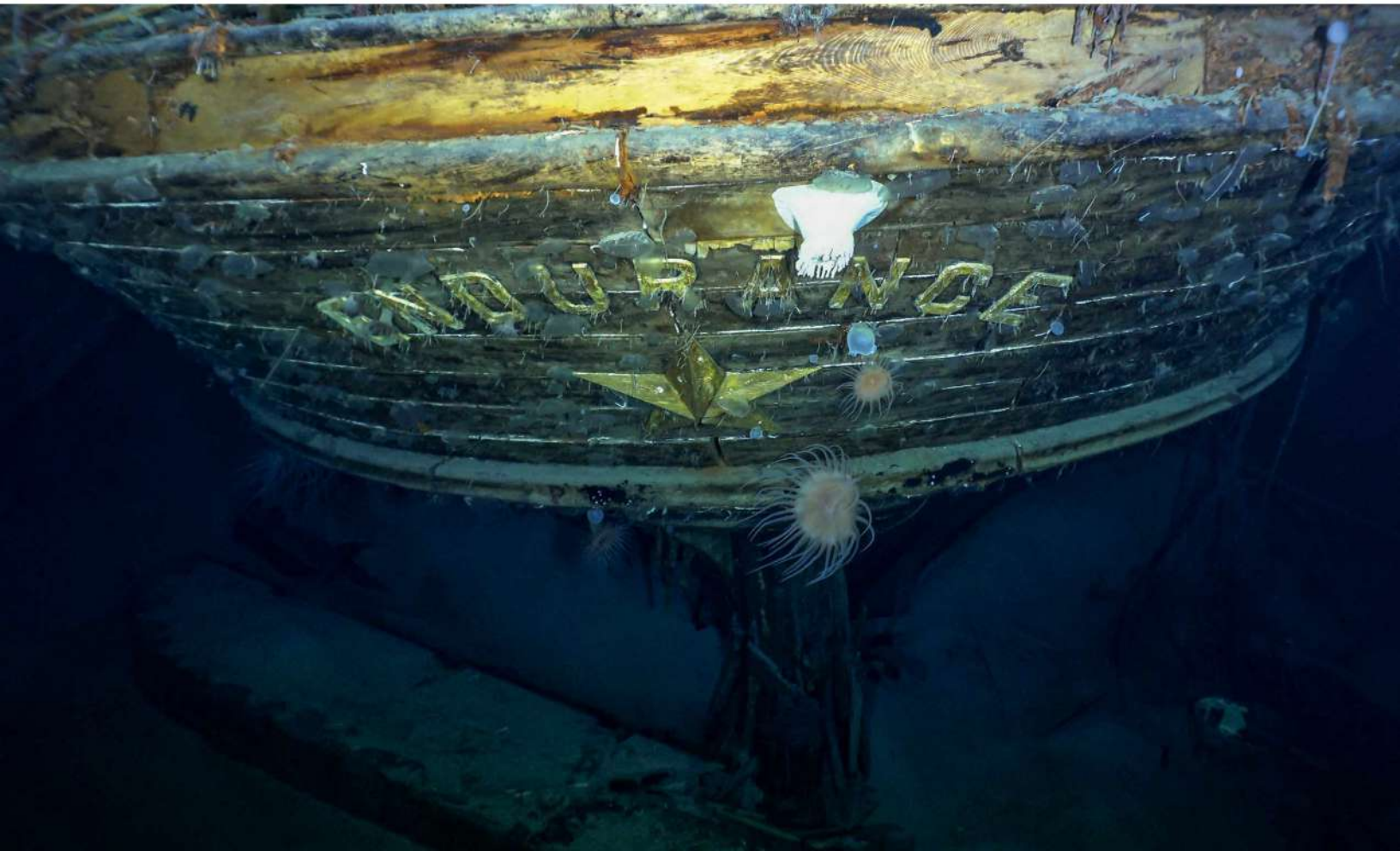
This stunning image beamed to Earth by the James Webb Space Telescope (JWST) reveals details of far-flung regions of the Milky Way that we've never seen before. Launched on Christmas Day 2021, from a spaceport in French Guiana, the JWST is the largest telescope ever sent into space. It uses infrared light to show us stars that were previously obscured from view by dust. Its first images, broadcast here to crowds in Piccadilly Circus, London, show the edge of a star-forming region around 7,600 light-years from Earth, in the Carina Nebula, which is home to stars millions of times brighter than our Sun.

ALAMY

Hole at the heart of the Galaxy

EVENT HORIZON TELESCOPE
12 MAY

You would have thought if there was a supermassive black hole at the centre of the Galaxy, we'd have noticed it before. But that's the thing about black holes: you can't see them. You can only see the gas whirling around them. The one at the centre of the Milky Way, named Sagittarius A*, is around 27,000 light-years away from Earth and we only found it by training eight radio telescopes on it all at the same time. It took 300 researchers and their supercomputers five years to analyse the data they collected before they could finally release this first portrait of the previously unseen object.

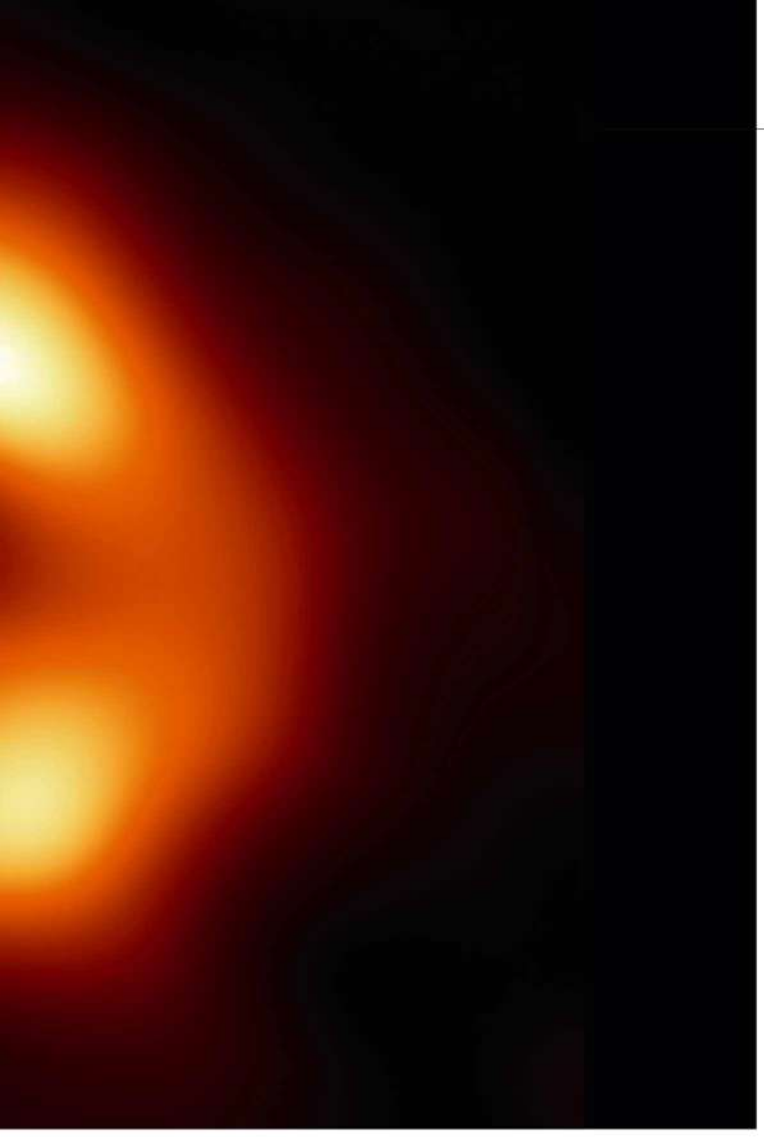


Big baby mummy

YUKON, CANADA
21 JUNE

This 30,000-year-old baby woolly mammoth, 'Nun cho ga' (big baby animal), takes her name from the Hän language spoken by Indigenous peoples in Yukon, Canada, where she was found in June. Nun cho ga's remains were discovered by gold miners and rescued by geologists. It's thought she probably died after getting stuck in mud, which would have initially preserved her body, but permafrost kept her intact over the millennia. DNA has previously been extracted from much older mammoths, but none so well preserved. Her future is in the hands not just of scientists, but also of the Tr'ondëk Hwëch'in people who own the land where she was found.

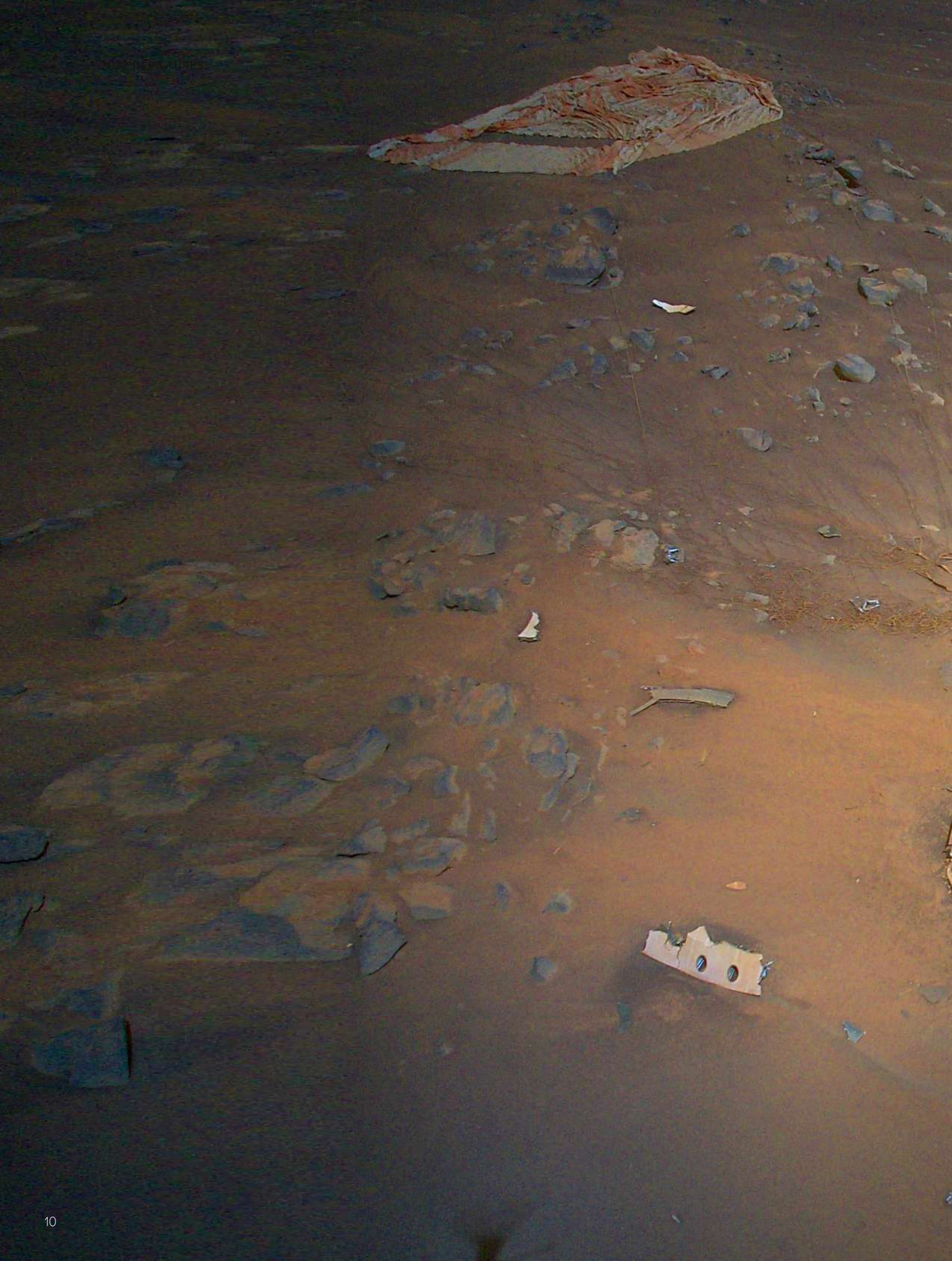
ESO, FALKLANDS MARITIME HERITAGE TRUST, GOVERNMENT OF YUKON



Shackleton's lost ship

WEDDELL SEA
5 MARCH

In 1915, the 28-strong crew of Ernest Shackleton's *Endurance* found themselves stranded as the explorer's ship hit pack ice off the coast of Antarctica. Their 1,300km expedition to safety – involving death-defying journeys on small lifeboats – is a tale as harrowing as it is inspiring. So it's no wonder that the discovery of their lost ship (pictured here from the stern) reignited interest in the story. After a previous failed attempt in 2019, *Endurance* was finally located 3km down and intact by a team working with autonomous and remotely operated vehicles from a polar research vessel. Icy currents had caused it to drift, but ultimately it lay just 6km from its last known position recorded over a century earlier.



The ruins of success

JEZERO CRATER, MARS
19 APRIL

These shattered remains may look like a failed space mission, but they're very much a sign of success – for two reasons. First, these are the backshell and parachute of NASA's Perseverance rover – landing gear the robot no longer needed after surviving a 126km/h descent to the surface of Mars in 2021. Second, the picture was taken by Ingenuity, a miniature helicopter with a metre-wide rotor span that caught a ride to the Red Planet with the rover. Ingenuity has a flight range of only 300m but, as of November 2022, had clocked up 34 flights and covered a total of 7km. Images like these help NASA to understand whether a landing occurred as expected and what could be improved for future missions.

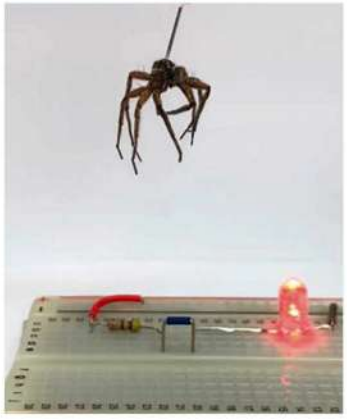
NASA/JPL

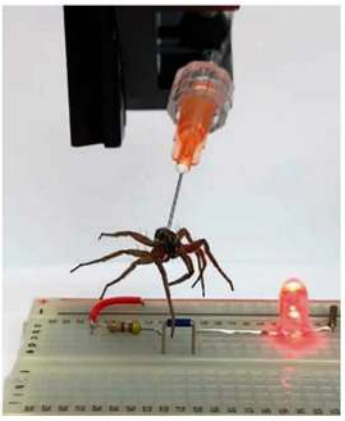
One of a kind

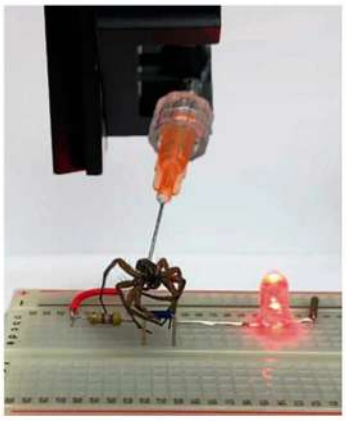
SERVION, SWITZERLAND
MAY

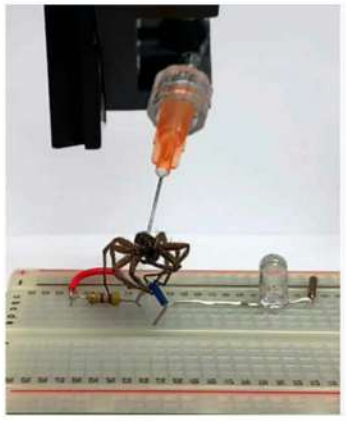
Hatched at a Swiss zoo in May, this newborn tortoise is the first example of an albino Galapagos giant tortoise (*Chelonoidis nigra*) known in captivity or the wild. Its mother, pictured in the background, and sibling are both black. According to the zoo, albinism is rarer in tortoises than in humans, with the chance of any tortoise being albino estimated to be around 1 in 100,000. However, while this baby may be unique, its lack of the skin pigment melanin makes it particularly susceptible to skin cancer. In the wild, this extra threat to an already endangered species would seem to make survival unlikely, but in captivity it can be kept out of sunlight.

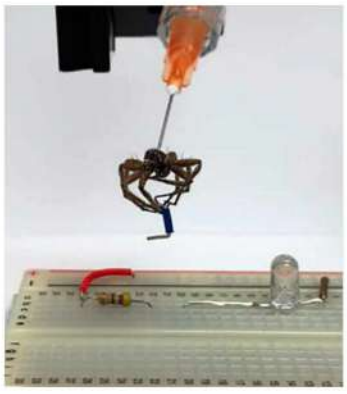
GETTY IMAGES, NICHOLAS PAPAS, ESA, NASA/JPL











Spiderbot

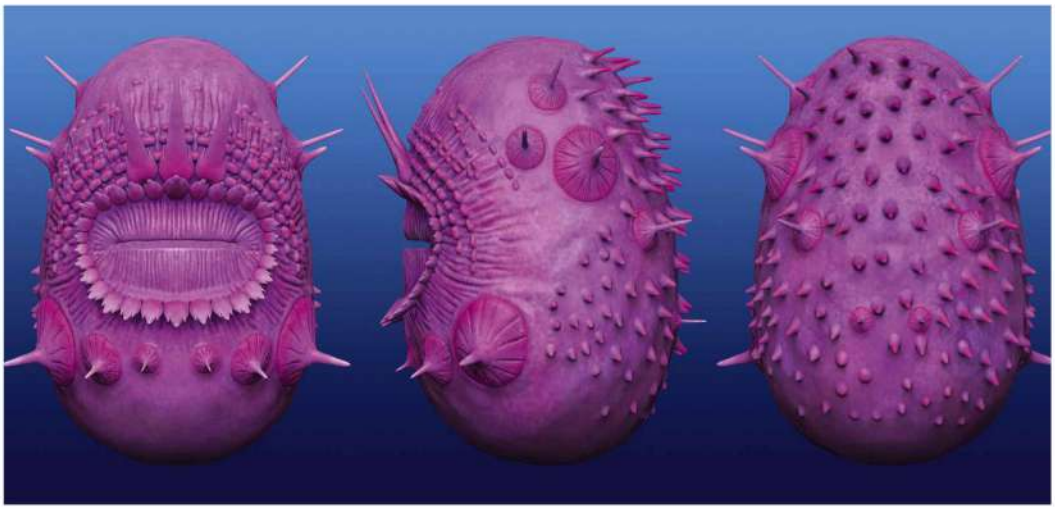
RICE UNIVERSITY, TEXAS
25 JULY

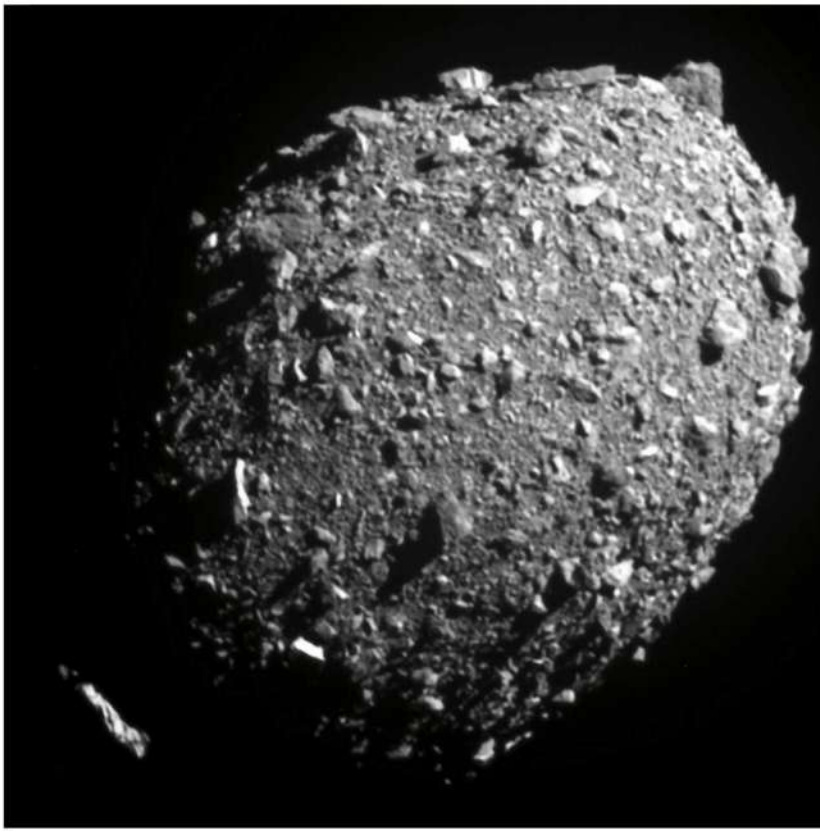
Researchers from Rice University thought it would be fun to turn a dead spider into a robotic gripper, in order to pick up other objects. Overkill, perhaps, but they claim that it heralds a new era of 'necrobotics' (robots made from dead things). Actually, their technique is pretty simple: take a spider, stick a syringe in it, then apply pressure by squirting air into its cold, dead body. This works because spiders use hydraulics to force haemolymph (their version of blood) into their limbs, forcing them to extend. When spiders die, they lose this ability, and so they curl up.

No bum non-ancestor

INTERNATIONAL RESEARCH TEAM
17 AUGUST

Are we descended from a 530-million-year-old animal with a giant mouth and no anus? Apparently not. Well, good. That's one thing scientists have sorted out this year. We're all done here. Unless, of course, you're wondering whose family tree this bumless blob (officially *Saccorhytus coronarius*) belongs to. The answer, according to the latest thinking, is crabs, spiders and roundworms. Previous evidence linking it to our line was based on limited specimens. The new work, involving high-resolution imaging and many specimens, enabled researchers to create the detailed reconstructions shown here.





T-minus 11 seconds

DIMORPHOS
26 SEPTEMBER

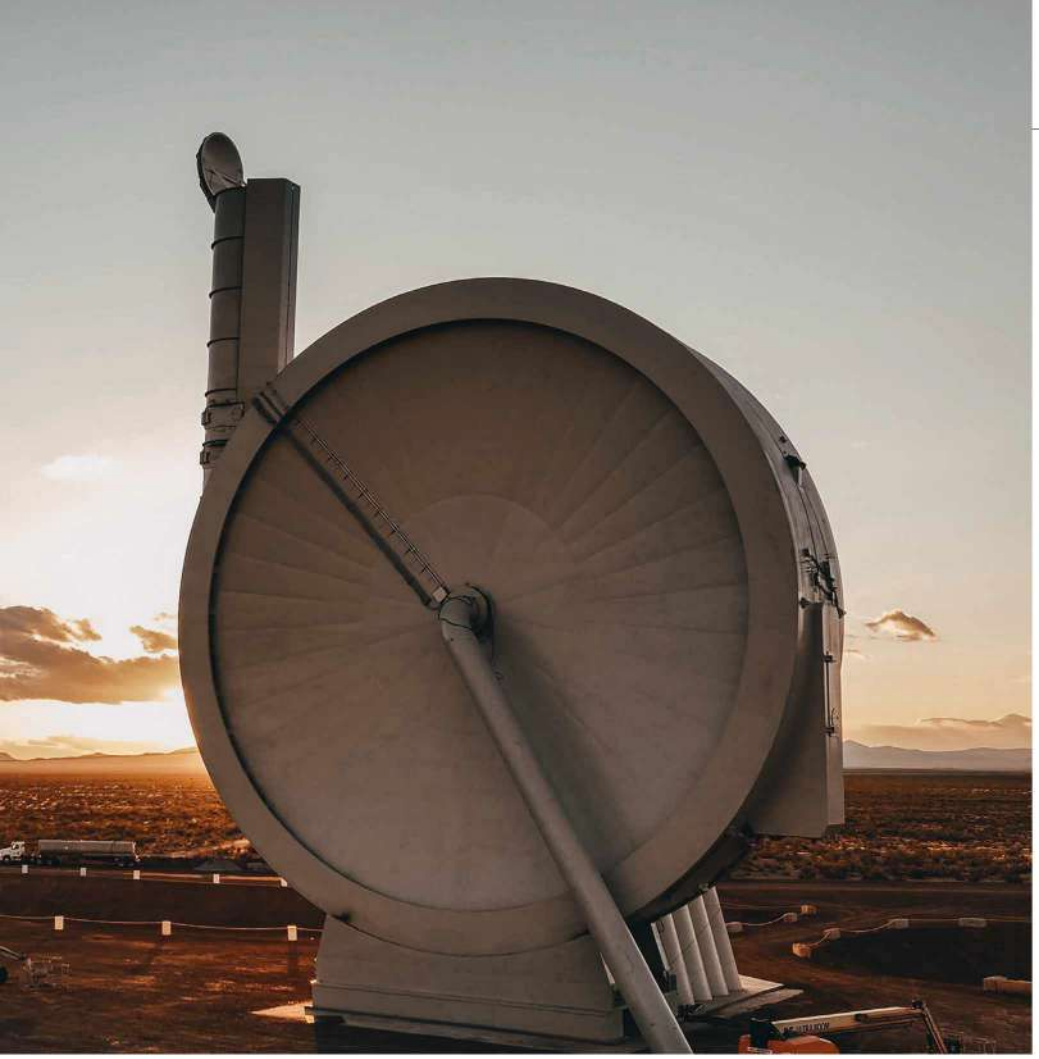
This was one of the last images NASA's DART (Double Asteroid Redirection Test) spacecraft transmitted. Just 11 seconds later, it crashed into its target, the asteroid Dimorphos (pictured here from 68km away), at around 24,000km/h. Despite being fatal for the spacecraft, the mission proved a hit for the US space agency. After crunching the data, it confirmed that DART had successfully altered the trajectory of Dimorphos in its orbit around its parent asteroid, Didymos. So, hopefully, when bigger, badder asteroids look set to destroy Earth, we now have the knowledge to send them off-course.

GETTY IMAGES, PRESTON INNOVATION LABORATORY/RICE UNIVERSITY, NIGPAS, NASA/JPL

Tiny tower block

UNIVERSITY OF CAMBRIDGE, UK
7 MARCH

Two-thirds of a millimetre might not sound very tall, but when you're a bacterium, it's bigger than the Empire State Building. It's also the height of these 600-micrometre-high 'nano-skyscrapers', which are actually tiny 3D-printed towers of electrodes that UK researchers built to house light-harvesting organisms called cyanobacteria, which make their energy via photosynthesis, just like plants. The towers are designed to cram in as many cyanobacteria as possible while maximising their exposure to sunlight. By plugging into the electrodes, the scientists show that it's possible to use cyanobacteria as a source of sustainable energy.



Satellite spinner

NEW MEXICO, USA
SEPTEMBER

This is SpinLaunch: a prototype system for launching satellites and other payloads into space using kinetic energy instead of the chemical fuel in traditional rockets. The prototype is a third of the size of the planned 100m-wide full-scale system, but is capable of spinning payloads at 8,000km/h and 10,000G before flinging them skyward through a launch tube. Although small rocket engines will still be needed to get payloads into orbit, it's claimed the system cuts down on fuel and infrastructure by around 70 per cent. In April, SpinLaunch signed a 'Space Act Agreement' with NASA and by September was testing the system with components of the space agency's own satellites.

GABRIELLA BOCCHETTI, SPINLAUNCH, NASA/ESA

Historic mission

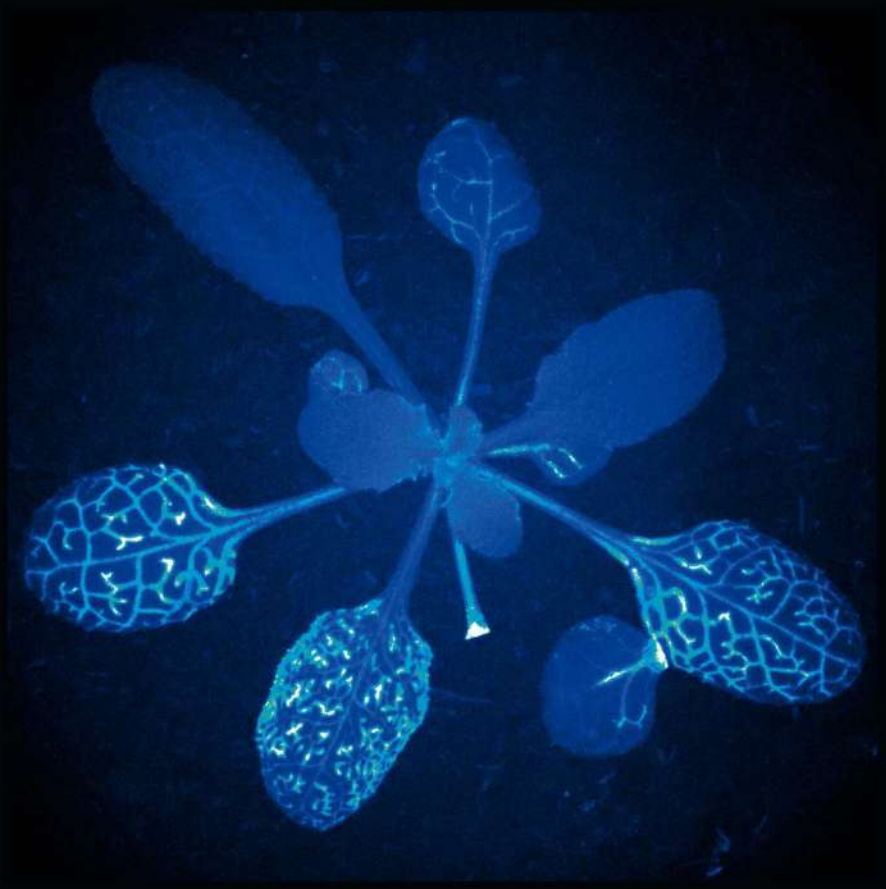
INTERNATIONAL SPACE STATION
22 JULY

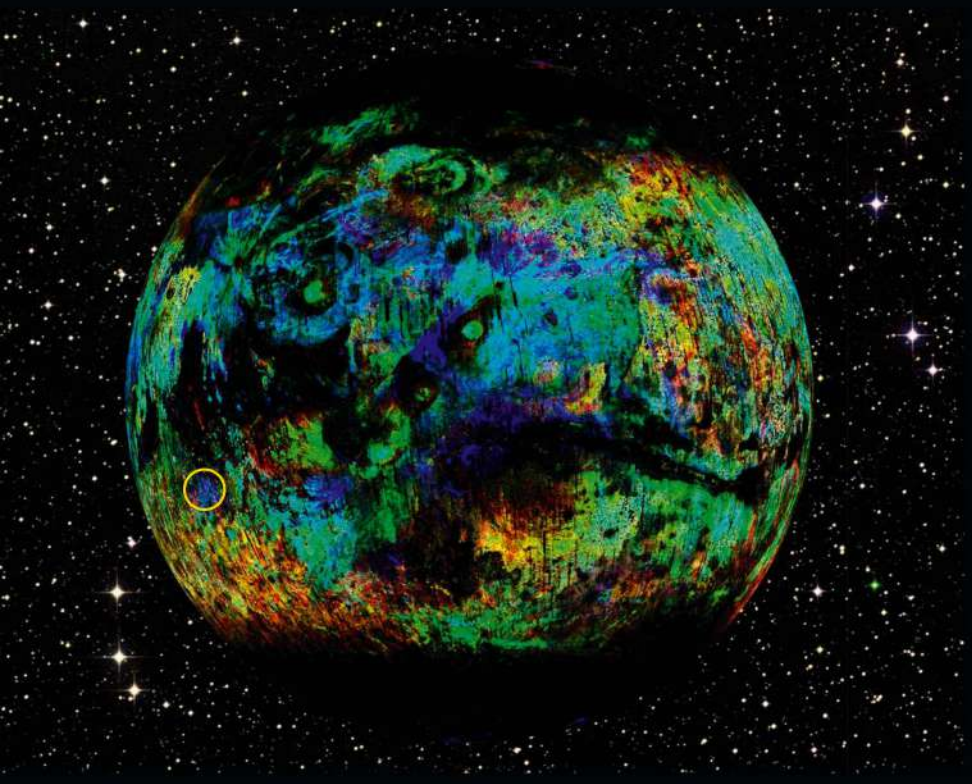
On 22 July, Samantha Cristoforetti emerged from the airlock of the International Space Station (ISS) as the first-ever European woman to take a spacewalk. There was no time to bask in the glory though, as the Italian astronaut had work to do on the new European Robotic Arm (ERA), a robotic attachment to the space station designed to cut down on the need for human spacewalks. Staying outside for seven hours in all, she and Russian cosmonaut Oleg Artemyev installed new parts on the ERA. In September, Cristoforetti became the first female European commander of the ISS before returning to Earth safely in October.

Plants in pain

NORWICH, UK
21 OCTOBER

Plants don't have nerves. For a long time, though, scientists were fascinated by the fact that they seemed to deploy one of the chemical messengers that humans use to transmit nerve impulses – calcium – when they get injured. However, this year, scientists at the John Innes Centre in the UK used new fluorescent imaging techniques (pictured here in cress seedlings) to show that this calcium rush isn't a moving wave or impulse. Instead, it's a response to another chemical, glutamate, that's released at the injury site. Glutamate molecules travel along the corridors between plant cells, triggering the opening of cell 'doors' that let out calcium as they go. So it's glutamate, not calcium, that's the messenger.





Black Beauty's birthplace

CURTIN UNIVERSITY, AUSTRALIA
12 JULY

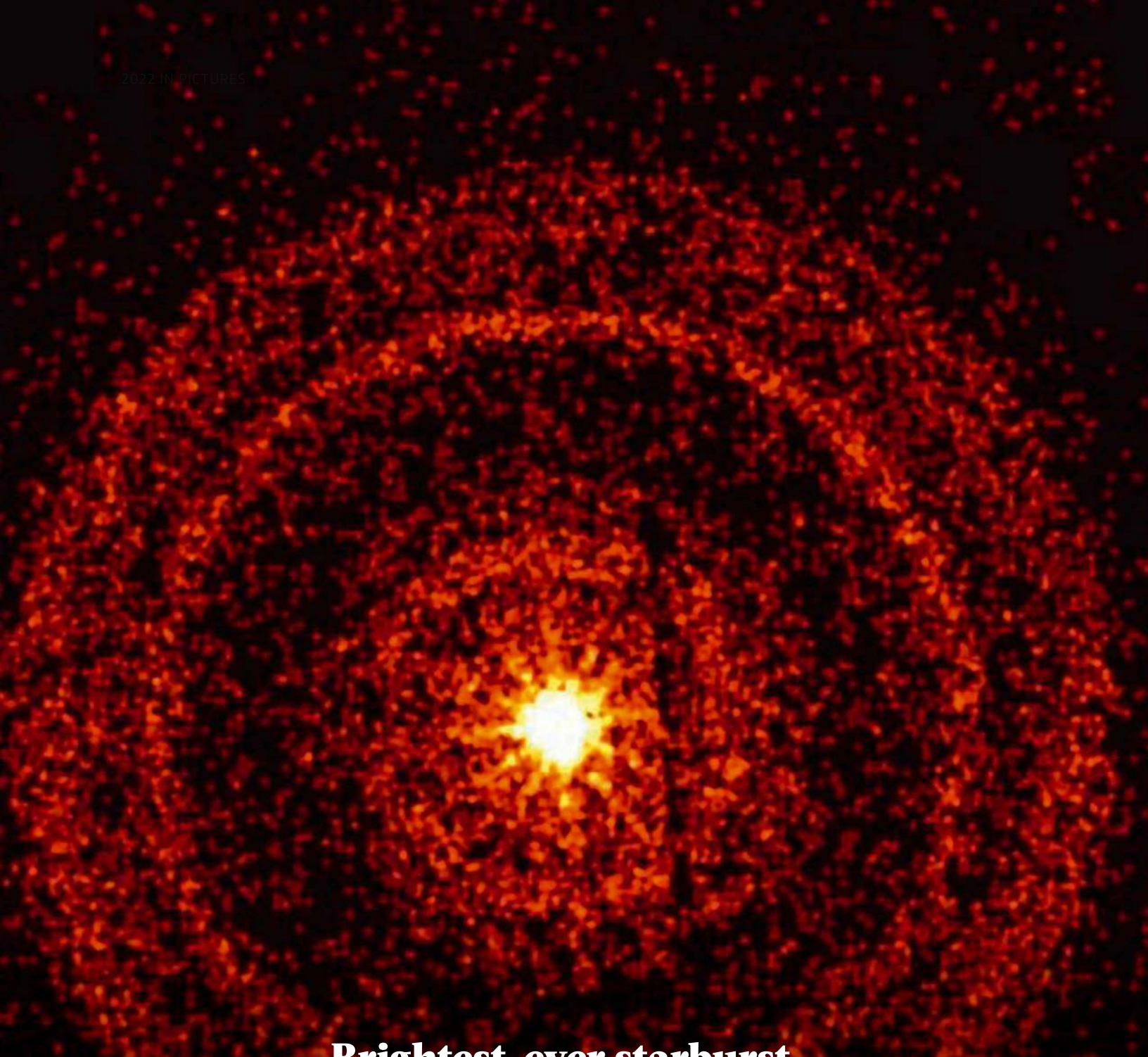
In 2011, a nomad named Bahba picked up a lump of black rock in the Sahara Desert. It turned out to be a piece of 4.5-billion-year-old meteorite forged in magma chambers below the surface of a young Mars and flung to Earth when a comet hit the Red Planet 5-10 million years ago. Now known as 'Black Beauty', it took scientists until this year to pinpoint the meteorite's origins in the Terra Cimmeria-Sirenum province (circled). The Australian team did it by analysing 94 million Martian craters, colour-coded here by age and size. Given Black Beauty is so old, they think the region could hold clues to the planet's early history.

ANNALISA BELLANDI, ODYSSEAS CHLORIDIS, LAGAIN ET AL/NATURE COMMUNICATIONS

Hiking hotspot

REYKJANES PENINSULA, ICELAND
3 AUGUST

Iceland is well known for its lava fields, but new volcanic activity on the Reykjanes peninsula close to Reykjavik is proving particularly accessible to day-trippers from the capital. This eruption in the Meradalir Valley, starting on 3 August, attracted thrill-seeking hikers to a 300km fissure in the Earth's crust that, within a fortnight, had spewed out 10 million cubic metres of lava. It came just a year after another large vent opened up a kilometre away. Until then, the region hadn't seen any major volcanic activity since the 12th Century, when medieval Iceland was ruled over by chieftains known as goðorð.



Brightest-ever starburst

NEIL GEHRELS SWIFT OBSERVATORY
9 OCTOBER

Gamma-ray bursts (GRBs) emanate from high-energy explosions occurring when massive stars much hotter than our Sun collapse to form black holes or neutron stars. Pictured is GRB 221009A, the brightest GRB ever witnessed, detected on 9 October and lasting a full 10 hours. It was so bright that even the Fermi Gamma Ray Space Telescope – designed specifically for GRBs – couldn't deal with what it was emitting. But as the energy emitted by such an explosion is converted into different kinds of radiation, the X-ray telescope aboard the Neil Gehrels Swift Observatory was able to capture this image from X-rays as they bounced off dust in the Galaxy. GRB 221009A took place about 1.9 billion light-years away, which is close in GRB terms.

War scene in a war zone

AL-RASTAN, SYRIA
12 OCTOBER

Part of this 120m² mosaic was unearthed in the Syrian city of Al-Rastan during the Syrian Civil War, but it's only now that archaeologists have been able to excavate it more completely. The 1,600-year-old artwork, photographed in October, depicts scenes of soldiers fighting in the Trojan War, which according to Greek mythology involved the Greeks sneaking into the city of Troy in a wooden horse. It may extend even further than 120m² – the excavation is still ongoing. Other artworks and places of historical importance, including mosaics and churches, were destroyed during the Syrian conflict in the last decade, but museum researchers still hope to discover more beneath the ruins.

NASA/SWIFT/A BEARDMORE/UNIVERSITY OF LEICESTER, GETTY IMAGES X2

Intelligent exoskeleton

MEXICO CITY, MEXICO
18 OCTOBER

The Atlas 2030 exoskeleton was specially designed for children by Spanish robotics engineer and inventor, Elena García Armada. Until now, exoskeletons have been a high-tech addition to rehab programmes for adult patients who have suffered strokes or traumatic brain and spinal injuries. But the suits can't just be downsized for children, whose physical limitations are more often related to neurological conditions – as in the case of David Zabala (pictured), who has cerebral palsy. These conditions require a more 'intelligent' suit that can read the intention of the walker and adapt its gait accordingly. SF

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

reply@sciencefocus.com
BBC Science Focus, Eagle House, Bristol, BS1 4ST
@sciencefocus
www.facebook.com/sciencefocus
@bbcsciencefocus

LETTER OF THE MONTH

Musical tombs

Could it be possible that Tutankhamun's tomb, KV62, was originally built by Tutankhamun to hold his relatives from el-Amarna, including Queen Nefertiti, and tomb KV55 was commissioned for his own burial (November, p68)? But because he died young, and before the tomb was ready, the priests would have been on a tight schedule to get the young pharaoh entombed. So they utilised KV62 instead, the previous occupants being unceremoniously dumped In KV55, with all the respect befitting heretics who crippled Egypt at the time. Could the rather feminine images of Tutankhamun once attributed to Hatshepsut, be of Nefertiti?

Pat McDonnell, Crosshaven, Ireland

Both KV62 and KV55 are located right in the centre of the Valley of the Kings and are small tombs of similar design. It may be that they were originally intended for senior nobles, but KV62 was extended to include a crypt when it was pressed into service for the burial of Tutankhamun. There has been a lot of speculation that Tutankhamun originally started either KV23 (used by his successor Ay), or KV57 (used by Horemheb), without any firm proof. As far as we know, Tutankhamun salvaged the burials of his relatives from Amarna and placed them directly into KV55. He certainly usurped quite a lot of the funerary goods of Nefertiti, which, as you say, are often distinctly feminine in appearance. I'm not aware of similar speculation with regard to Hatshepsut. She dates to much earlier in the 18th Dynasty and her images would reflect the style of that age.

Dylan Bickerstaffe, Egyptologist

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **bundle of brilliant sci-fi books** from Pan Macmillan. The prize includes the space opera *Children Of Memory*, by award-winning author Adrian Tchaikovsky; the atmospheric Gothic sci-fi *Leech*, by Hiron Ennes; and the contemporary tale of love, space and time *Alone With You In The Ether*, by Olivie Blake, the author of the much-acclaimed *The Atlas Six*.

panmacmillan.com

Black hole paradox

I listened to your podcast entitled *Holding The Universe In Your Hands*, with Dr Kimberly Arcand. In the discussion on the 'sound' of a black hole, I was able to imagine (most likely incorrectly) the sound being generated by matter rushing towards the black hole, pretty much like a vacuum. This did prompt a question for me: if matter is being sucked into a black hole (to where even Brian Cox doesn't know), does this contradict the laws of the conservation of the mass and energy, as mass and energy are not being returned to the system? Or, are they being returned to the system, and the black hole (and beyond) is still part of the system?

Jim Slattery, Co. Limerick

The pressure waves/sound waves are moving outwards from the area of the black hole system (versus matter rushing towards the black hole). The sound waves are thought to have been generated by cavities blown out by jets from the supermassive black hole at the centre of the Perseus Cluster of galaxies. Supermassive black holes can pull material swirling around them into their gravitational

Jim Slattery ponders the 'sound' of a black hole

"I'VE NEVER HEARD SOMEONE SAY 'SO-AND-SO IS A REALLY GOOD SMOKER, HE CAN REALLY HOLD HIS FAGS'. THERE'S STILL THAT HEROIC IMAGE AROUND DRINKING"

SIR IAN GILMORE, P66

Self-driving buses could help make public transport a more viable option, says Luke Russell

GETTY IMAGES X2, ALEXANDER DENNIS GROUP, ALCOHOL HEALTH ALLIANCE

grasp. During this process, some of this material is redirected away from the black hole in the form of energetic narrow beams, or jets. Such jets can significantly affect how the galaxy and its surroundings evolve.
Kimberly Arcand, visualisation scientist

Self-driving cars

I read the article on self-driving cars (November, p44) with great interest. I am in agreement with Prof Jack Stilgoe that the rollout of self-driving cars is going to be a slow process, and the UK government's target of 2025 will be limited to most likely vehicles on motorways. The area this technology needs to be applied to is buses. In the post-COVID years, service levels have become appalling. Staff shortages and illnesses seem to have no end in sight. It will not only end these issues, but it'll also massively reduce costs for service providers, meaning that bus routes that previously were unviable become possible, meaning (hopefully) better service provision.
Luke Russell, Tingley

Follow us on Instagram!
Discover incredible photography, science news and jaw-dropping tech, all in bite-size chunks, straight to your feed.
@bbcsciencefocus
instagram.com/bbcsciencefocus/

THE TEAM

EDITORIAL
Editor Daniel Bennett
Managing editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Digital editor Thomas Ling
Staff writers Alex Hughes, Holly Spanner

ART
Art editor Joe Eden
Picture editor James Cutmore

CONTRIBUTORS
Claire Asher, Scott Balmer, Rob Banino, Steve Benford, Hayley Bennett, Peter Bentley, Steve Boswell, Daniel Bright, Steve Brusatte, Daniel Crespo, Kate Darling, Emma Davies, Sam Falconer, Amy Fleming, Sam Freeman, Alice Gregory, Wendy Hall, Matt Holland, Christian Jarrett, Stephen Kelly, Pete Lawrence, Katie Mack, Nish Manek, Holly McHugh, Michael Mosley, Stephanie Organ, Jheni Osman, Helen Pilcher, Helen Scales, Julia Shaw, Valentin Tkach, Luis Villazon, Joe Waldron, Kimberley Wilson, James Witts.

ADVERTISING & MARKETING
Business development manager David D'Souza
Newstrade manager Rob Brock
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane

MOBILE
Head of apps and digital edition marketing Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION
Production director Sarah Powell
Production coordinator Lauren Morris
Ad services manager Paul Thornton
Ad designer Julia Young

PUBLISHING
Publisher Andrew Davies
Group managing director Andy Marshall
CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING
Chair, editorial review boards Nicholas Brett
Managing director, consumer products and licensing Stephen Davies
Director, magazines and consumer products Mandy Thwaites
Compliance manager Cameron McEwan
UK publishing coordinator Eva Abramik
Contact UK.Publishing@bbc.com
www.bbcstudios.com

EDITORIAL COMPLAINTS
editorialcomplaints@immediate.co.uk

ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £77; Europe & Eire £92.54;
Rest of World £102.90.

Audit Bureau of Circulations
50,142 (combined, Jan-Dec 2021)

BBC Science Focus Magazine is published by Our Media Ltd (an Immediate Group Company), under licence from BBC Studios who help fund new BBC programmes.

© Our Media Ltd 2022. All rights reserved. Printed by William Gibbons Ltd.

Our Media Ltd accepts no responsibility in respect of products or services obtained through advertisements carried in this magazine.

recycle
When you have finished with this magazine please recycle it.

JANUARY Sale

Make discovering new passions your New Year's resolution in 2023!

Get started with a great value trial offer for one of our bestselling magazines.

3 ISSUES FOR £5

3 ISSUES FOR £5

3 ISSUES FOR £5

3 ISSUES FOR £5

3 ISSUES FOR £5

3 ISSUES FOR £5

3 ISSUES FOR £5

12 ISSUES FOR £1

3 ISSUES FOR £5

3 ISSUES FOR £5

3 ISSUES FOR £5

3 ISSUES FOR £5

GREAT REASONS TO SUBSCRIBE:

- Save up to 75% **+ free delivery**
- Continue to make **great savings** after your trial period
- **Never miss an issue** of your favourite magazine

2 EASY WAYS TO ORDER

Visit **buysubscriptions.com/JS23SP**

Call **0330 053 8660**† quote code **JS23SP**

Trusted Service Award 2022 feefo

*This offer closes on 31st January 2023 and is valid for UK delivery addresses and by direct debit only. The discounts shown are savings calculated as a percentage of the full shop price, excluding Radio Times which is calculated as a percentage of the basic annual rate. For overseas rates visit www.buysubscriptions.com. Should the magazine ordered change in frequency; we will honour the number of issues and not the term of the subscription. You are free to cancel your subscription at any time – if you cancel within 2 weeks of receiving your penultimate issue you will pay no more than the trial rate, this is except for Radio Times, which you will need to cancel 3 weeks before the trial is due to end. Radio Times is published weekly and the Basic Annual UK Subscription rate for Radio Times is £238. This price is for one year and includes the Christmas double issue and a contribution towards postage. These rates are correct at time of printing. We run trial offers throughout the year to give our customers an opportunity to try a new title before committing to a long-term subscription. These are introductory offers, and we reserve the right to reject or cancel any application for a trial subscription offer if the customer has previously purchased a trial offer for the same magazine or any other magazine in the Immediate Media portfolio. For a full list of our titles visit buysubscriptions.com/portfolio. †UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am – 5pm.

DISCOVERIES

"The animals of the Ediacara biota were a mixed bag of downright weirdoes"

Dr Ilya Bobrovskiy **p28**

You may know that bats chirrup to echolocate, but did you know they grunt like death-metal singers to communicate with each other?

PALAEONTOLOGY

FIRESTARTERS

Evidence suggests another species of hominid may have harnessed fire **p24**

BIOLOGY

A SPOONFUL OF FAKE SUGAR

Artificial sweetener may help us beat antibiotic-resistant bugs **p26**

MEDICINE

X-RAY VISION

AI can predict your risk of heart disease from a chest X-ray **p27**

PALAEONTOLOGY

WHAT DID YOU EAT LAST?

Evidence of the last meal eaten by one of the first large animals found **p28**

ZOOLOGY

BATS ARE METALLERS

Well... they communicate in a range that's equivalent to death-metal singers **p29**

HEALTH

GRAVITY HATES YOUR GUTS

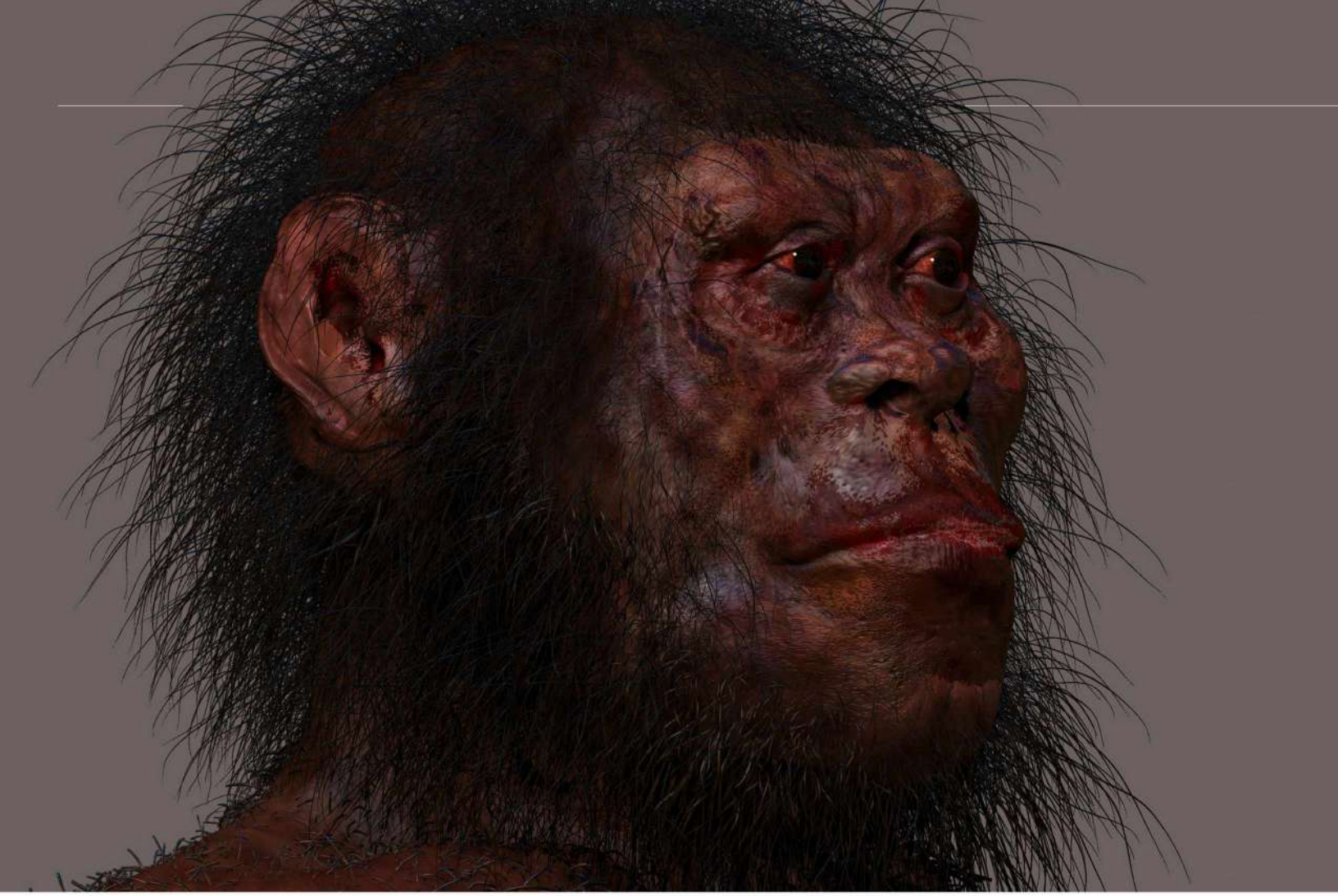
Could gravity be to blame for irritable bowel syndrome? **p30**

SPACE

VENUS LIFELESS AFTER ALL?

Analysis of planet's atmosphere suggests no phosphine present **p31**

ALAMY



PALAEONTOLOGY

LIKE MODERN HUMANS, *HOMO NALEDI* HARNESSED FIRE FOR LIGHT, WARMTH AND COOKING

Researchers excavating South Africa's Rising Star cave system have unearthed evidence that *Homo naledi*, an extinct species of hominid discovered in 2013, built fires in underground chambers

ABOVE An artist's impression of a male *Homo naledi*

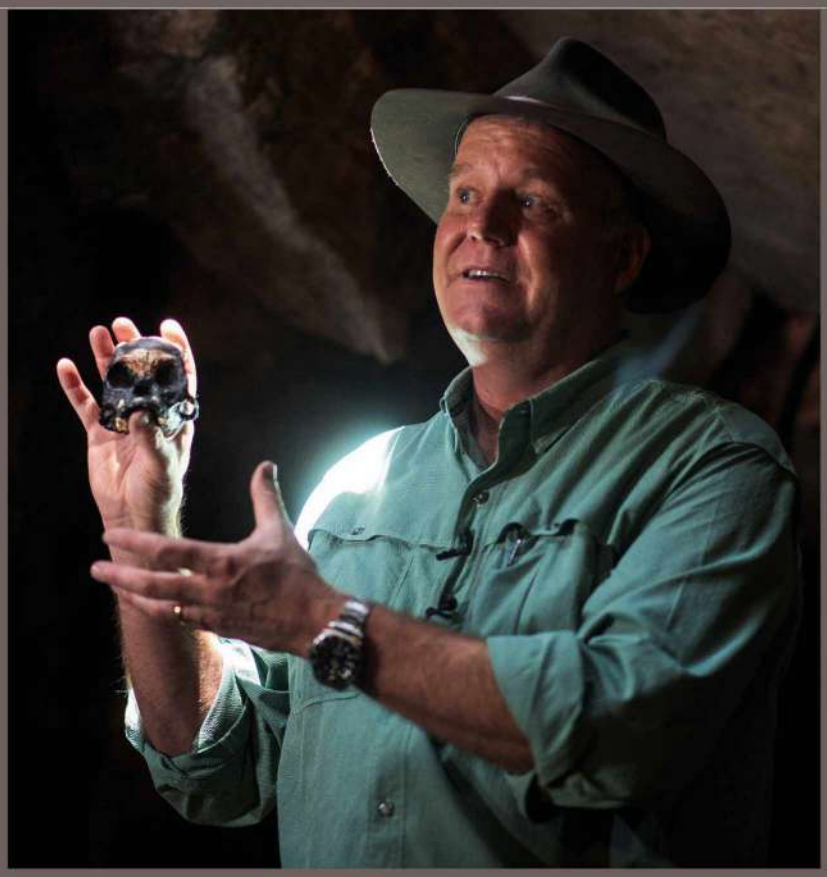
It's often said the ability to make fire is one of the key skills that defines *Homo sapiens* – it allowed our ancestors to cook food, keep warm and eventually become the most dominant species on the planet.

Recently, evidence has been found across Europe to suggest that Neanderthals were also skilled fire users, but now we may have to add another species to the list. Researchers excavating a complex network of caves in South Africa say they have unearthed evidence that *Homo naledi*, an extinct species of hominid that lived 200,000 to 300,000 years ago, also used fire.

The finding was announced at a lecture given at the Carnegie Institution of Science in Washington, DC, on 1 December by Prof Lee Berger of the University of the Witwatersrand, Johannesburg.

"We're fairly confident to formulate the hypothesis that this small-brained hominid, *Homo naledi*, [which] existed at the same time we believe *Homo sapiens* were sharing parts of Africa, was using fire for a variety of purposes," he said.

H. naledi was discovered in 2013 by a team of excavators, led by Berger. The remains were found hundreds of metres into a claustrophobically tight network of passages known as the Rising Star cave system near Johannesburg.



SCIENCE PHOTO LIBRARY, GETTY IMAGES X2, LEE R BERGER/NATIONAL GEOGRAPHIC

ABOVE LEFT Prof Lee Berger with a replica *Homo naledi* skull

TOP RIGHT Some of the charcoal found in the Rising Star caves

ABOVE RIGHT A reproduction of what's believed to be the skull of a *Homo naledi* child found in the Rising Star caves

"There were blackened areas across the wall. There were soot particles across the whole of the surface"

Subsequent excavations have since unearthed fossils from more than a dozen individuals (male and female, juvenile and adult) as well as evidence of ritualistic burial practices in which the remains of certain individuals appear to have been washed and deliberately placed in position.

Then, earlier this year, Berger finally entered the difficult-to-reach network of caves for the first time himself. And once he was inside the chamber where his team found the *H. naledi* remains, he noticed evidence of soot on the cave's surfaces.

"As I looked up and stared at the roof, I began to realise that the roof was not a pure calcium carbonate. The roof above my head was grey above fresh flowstone. There were blackened areas across the wall. There were soot particles across the whole of the surface. The entire roof of the chamber where we have spent the last seven years working is burnt and blackened," he said.

At the same time, the expedition's co-director, Dr Keneiloe Molopyane, uncovered the remains of a small hearth containing burnt antelope bones, as well as the remains of a much larger hearth in a nearby cave.

Further investigation of the cave system led to the team finding several other caves and passages containing chunks of burnt wood and charred animal bones.

"Fire is not hard to find. It's everywhere within this system," said Berger. "Everywhere there's a complex juncture, they built fire. Every adjacent cave system to the chambers where we believe they were disposing of the dead, they built fires and cooked animals. And in the chamber where we believe they were disposing of the dead, they built fire but didn't cook animals. That's extraordinary."

The team now plans to work on radiocarbon dating their finds in an attempt to confirm the link between the hearths and the *H. naledi* fossils.

"This is the most extraordinary period of exploration and discovery. And it's going to continue," said Berger.

BIOLOGY

ARTIFICIAL SWEETENERS FOUND IN SUGAR-FREE FOODS CAN KILL ANTIBIOTIC-RESISTANT BACTERIA

The discovery could help in the war against superbugs

The key to beating antibiotic-resistant bacteria could have been hiding in plain sight on our supermarket shelves.

Three artificial sweeteners that are commonly used in diet drinks, yoghurts and desserts can dramatically halt the growth of multidrug-resistant bacteria, a study carried out at Brunel University London has found.

The sweeteners saccharin, cyclamate and acesulfame-K inhibited the growth of two bacteria, *Acinetobacter baumannii* and *Pseudomonas aeruginosa*, which cause pneumonia and sepsis. These bacteria are on the World Health Organization's (WHO) list of 'priority pathogens' that urgently need new antibiotic treatments, thanks to the deadly threat they pose to those with compromised immune systems. The team found that acesulfame-K was particularly effective in preventing the bacteria from developing the biofilms that protect them from antibiotics.

When used in conjunction with antibiotics, all three sweeteners reduced the bacteria's resistance, meaning that lower doses of the drugs were needed for effective treatment.

"Artificial sweeteners are present in all diet and sugar-free foods," said study leader Dr Ronan McCarthy, a bioscientist at Brunel University London.

"We discovered that these same sweeteners that you have with your coffee or in your 'sugar-free' soda could kill very dangerous bacteria and make them easier to treat. This is exciting, because normally it takes billions of dollars and decades to develop a new antibiotic drug, whereas we found a compound which can not only fight the pathogenic bacteria but also reverse its resistance to already existing antibiotics."

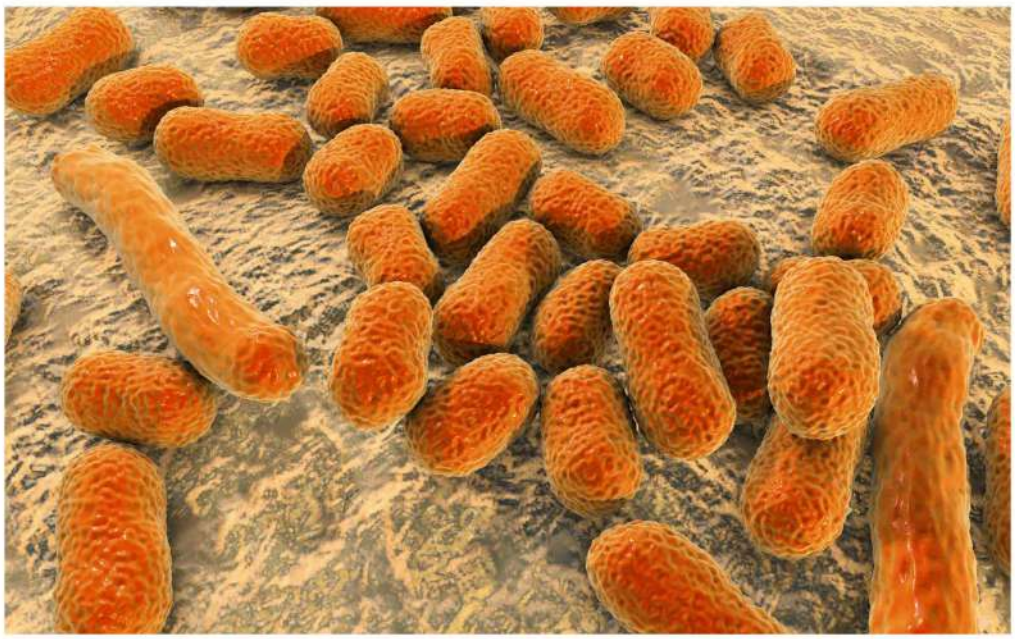
Antibiotic resistance arises thanks to bacteria's ability to adapt in response to antibiotics. It occurs naturally, but overprescribing drugs in humans and misuse in animals is accelerating the process. It is currently considered to be one of the biggest threats to global health and food security.

"It has created a dangerous situation where a 'post-antibiotic era' is becoming a reality," said McCarthy. "It threatens all aspects of healthcare, from cancer treatment to dental work."

The researchers now plan to run further tests and are optimistic that all three sweeteners could potentially offer new treatments for multidrug-resistant infection.

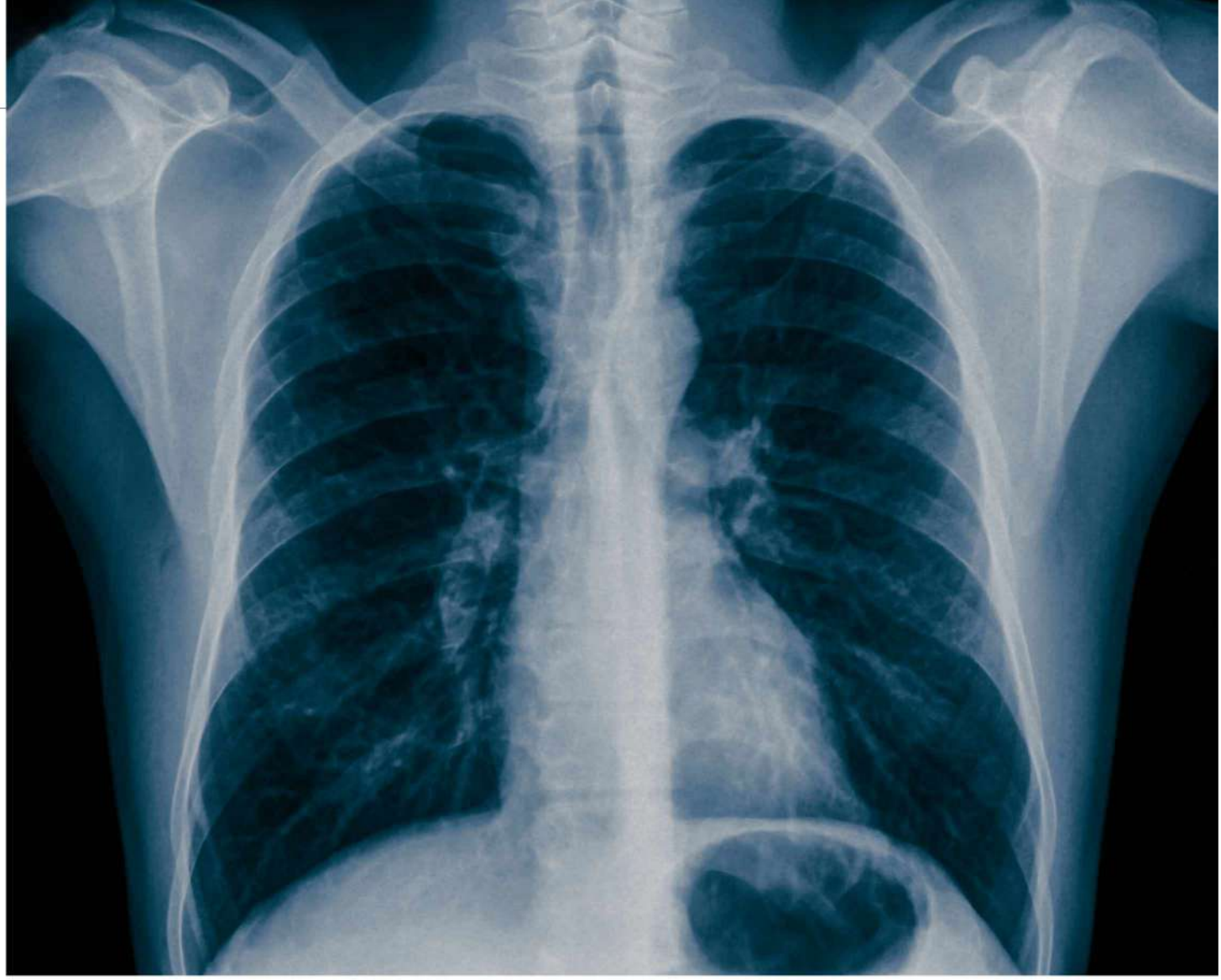
THE SWEET STUFF

Artificial sweeteners such as aspartame, acesulfame K and saccharin are chemical compounds used in place of sugar to sweeten food and drinks such as desserts, ready meals and soft drinks. They provide a sweet taste when consumed because their molecules are similar enough in shape to sugar molecules to fit on the sweetness receptors that line the tongue. Although some sweeteners contain calories, the quantities needed to provide a sweet taste are so small that their contribution to a person's overall daily intake is negligible.



BELOW *Acinetobacter baumannii* is a multidrug-resistant bacteria that causes infections in the blood, urinary tract and lungs

GETTY IMAGES, SCIENCE PHOTO LIBRARY



MEDICINE

AI CAN PREDICT THE RISK OF HEART DISEASE BY ANALYSING A SINGLE CHEST X-RAY

The model could be used to identify at-risk patients who are not currently taking preventative medication

Heart disease is one of the biggest killers in the UK. According to the British Heart Foundation, cardiovascular diseases are currently responsible for around a quarter of all UK deaths, which is around 160,000 deaths per year. Patients deemed to be most at risk are prescribed statins, which are drugs that lower the level of cholesterol in the blood and protect the insides of the artery walls. But signs of the disease are not always picked up early, meaning that many patients who would benefit from taking the drugs are not receiving them.

Now, researchers based at Massachusetts General Hospital have developed a deep learning AI model that can reliably predict a patient's 10-year risk of death from a heart attack or stroke by analysing a single chest X-ray.

The team trained the AI, named CXR-CVD Risk, using 150,000 chest X-rays taken from more than 50,000 participants in a prostate, lung, colorectal, and ovarian cancer screening trial carried out by the National Cancer Institute.

They then tested it on data taken from more than 11,000 patients with a mean age of 60 who were potentially eligible for statin therapy and who'd had routine outpatient chest X-rays.

They found that almost 10 per cent of the patients suffered a major cardiac event such as a heart attack or stroke within the 10-year period following the X-rays. Of these, the CXR-CVD Risk model was successfully able to predict 65 per cent.

"We've long recognised that X-rays capture information beyond traditional diagnostic findings, but we haven't used this data because we haven't had robust, reliable methods. Advances in AI are making it possible now," said Dr Jakob Weiss, of Massachusetts General Hospital.

"The beauty of this approach is you only need an X-ray, which is acquired millions of times a day across the world."

PALAEONTOLOGY

WORLD'S OLDEST MEAL FOUND IN 550-MILLION-YEAR-OLD FOSSILS

The bizarre ocean-dwelling creatures are relatives of all living animals

The contents of the last meal eaten by one of the world's first large animals has been discovered by researchers from the Australian National University (ANU). It is the earliest evidence of food eaten by an animal, they say. The team analysed a pair of Ediacara biota fossils, which are ancient forms of life that are the ancestors of all living animals and were the first creatures to develop bodies with features such as heads, tails and guts more than 550 million years ago.

To determine what the animals had been eating, they analysed the fossils in search of preserved phytosterol molecules, which are natural compounds found in plants. It turns out they ate green algae and bacteria.

One of them, a slug-like creature called *Kimberella*, ate via a mouth and digested the food in a gut much in the same way that modern animals do. The other – *Dickinsonia*, which looked a bit like a ribbed flatfish and measured 1.4m long – was a more basic beast with no eyes, mouth or gut, and likely absorbed food through its body as it moved along the ocean floor.

"Ediacara biota really are the oldest fossils large enough to be visible with your naked eyes, and they are the origin of us and all animals that exist today. These creatures are our deepest visible roots," said Dr Ilya Bobrovskiy from the GFZ German Research Centre for Geosciences in Potsdam, who collaborated on the research.

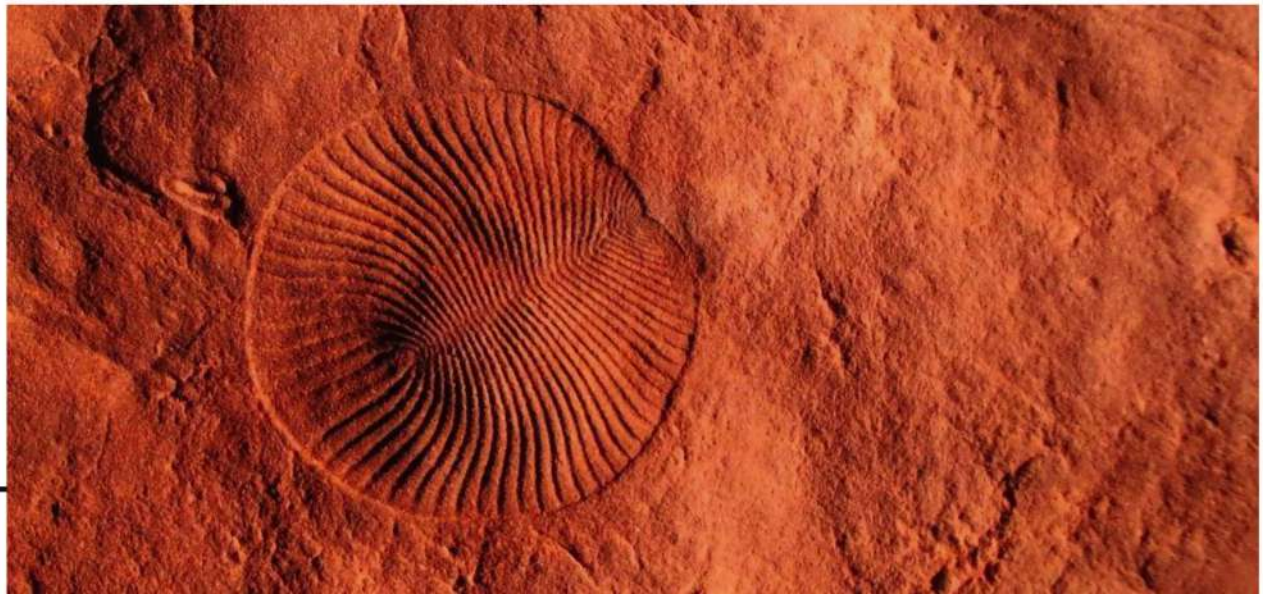
"Our findings suggest that the animals of the Ediacara biota were a mixed bag of downright weirdoes such as *Dickinsonia*, and more advanced animals like *Kimberella* that already had some physiological properties similar to humans and other present-day animals."

The researchers speculate that the energy-rich diet of Edicara biota may be one of the reasons they were able to grow so much larger than the microorganisms that came before them.

"Scientists already knew *Kimberella* left feeding marks by scraping off algae covering the sea floor, which suggested the animal had a gut," said the study's co-author Prof Jochen Brocks of ANU.

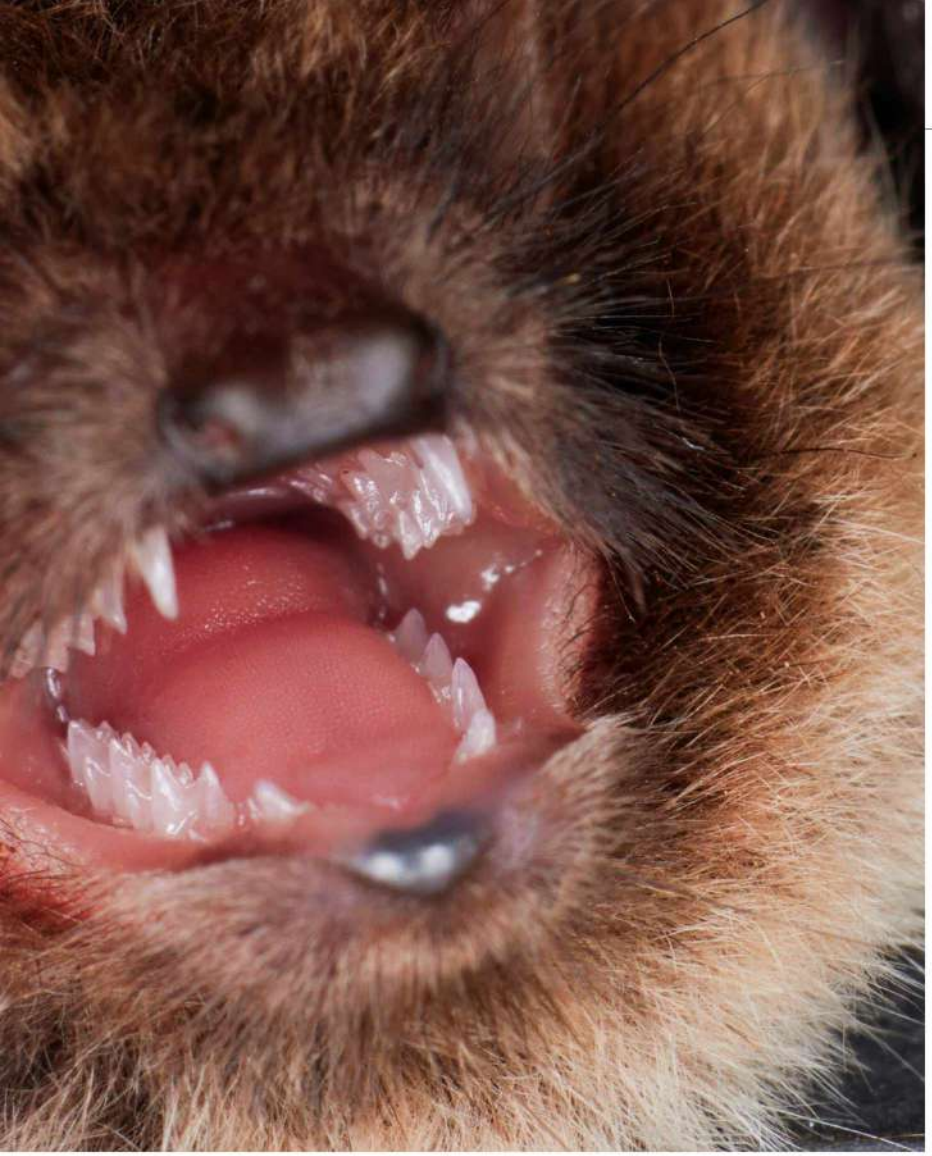
"But it was only after analysing the molecules of *Kimberella*'s gut that we were able to determine what exactly it was eating and how it digested food."

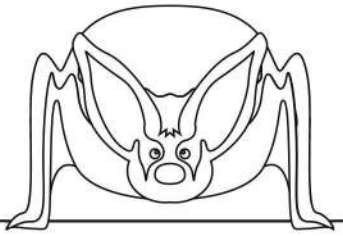
"Animals of the Ediacara biota were a mixed bag of downright weirdoes such as *Dickinsonia*, and more advanced animals like *Kimberella*"



RIGHT
Dickinsonia **fossils look a bit like ribbed flatfish, but in reality they were far simpler animals**

SCOTT EVANS, ALAMY





Many bats, including all bats in Britain, hibernate from late autumn to spring. During this period, their heart rates drop to 20 beats per minute. When flying, their hearts can reach 1,000 beats per minute.

1,400 There are around 1,400 species of bat worldwide. They can be found in almost every corner of the planet, apart from areas with extreme climates such as the polar regions and deserts.

The oldest recorded living bat was a Brandt's myotis bat found in Siberia. It was captured in 2005, and bore a band put on it by researchers in 1964, making it at least 41.

ZOOLOGY

BATS GRUNT LIKE DEATH METAL SINGERS TO TALK TO THEIR ROOSTMATES

The animals use structures in their voice boxes in the same way as the extreme singers to produce deep, guttural sounds

It turns out that heavy metal singers and bats have more in common than their mutual love of the dark and a tendency to move in groups. They both use distinct structures in their larynxes, or voice boxes, to produce booming, demonic vocalisations, a study carried out at the University of Southern Denmark has found.

Echolocating bats are known to have an incredibly wide vocal range. They can make sounds spanning around seven octaves, which is pretty impressive, considering how even Mariah Carey can only manage five.

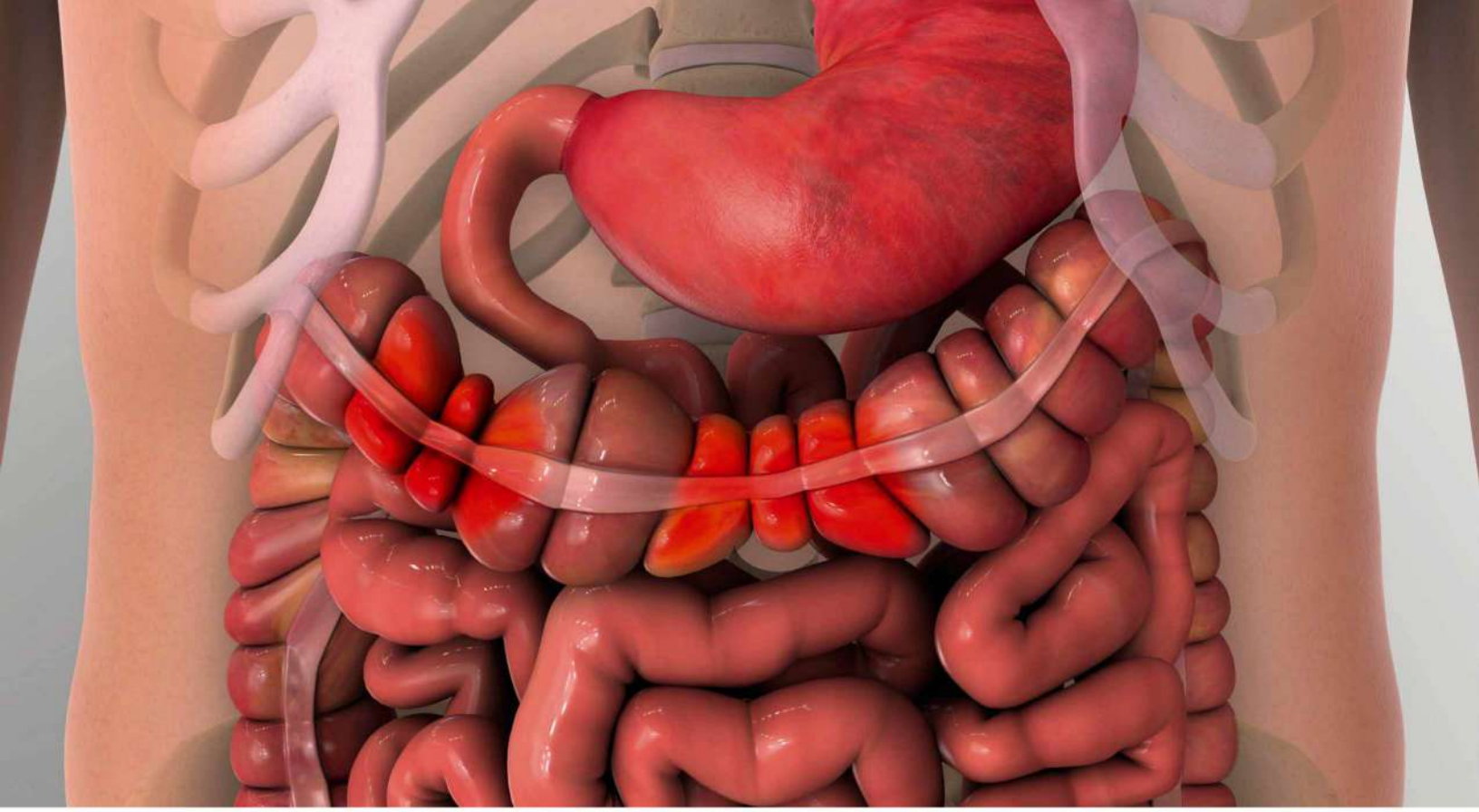
To investigate how they achieve such a feat of vocal gymnastics, the Danish team removed the larynxes from five adult Daubenton's bats, *Myotis daubentonii*, mounted them in a frame, applied an airflow designed to mimic the animals' natural vocalisations and filmed the movements with a high-speed camera that could image 250,000 frames per second. They then used machine learning models to reconstruct the motion of the bats' vocal membranes.

They found that the bats use a specific structure in their voice boxes known as false vocal cords that are not used in normal vocalisations to lower the frequency of their calls. The bats lower the false vocal folds down so that they oscillate together with their regular vocal cords. The additional weight this provides significantly reduces the pitch of the call. It is the same technique used by death metal singers to produce their trademark guttural growls.

The pitch of the growls is between 1 and 5kHz – the same pitch as the highest two octaves of a standard piano. Sounds that bats use for echolocation can reach frequencies of up to 120kHz.

The bats often make the growling sounds when they fly in and out of a densely packed roost, so it is unclear what their purpose is.

"Some seem aggressive, some may be an expression of annoyance, and some may have a very different function. We don't know yet," said the study's co-author Lasse Jakobsen.



HEALTH

IBS MAY BE CAUSED BY BODY'S INABILITY TO COPE WITH GRAVITY

The constant downward pull could lead to the gut pain and cramping experienced by sufferers

The cause of irritable bowel syndrome (IBS) has remained a mystery ever since it was first described more than a century ago. Now, Prof Brennan Spiegel at Cedars-Sinai Medical Center in Los Angeles, has published a theory in the *American Journal Of Gastroenterology* that suggests it could be caused by the body's inability to cope with gravity.

IBS affects around 10 per cent of the population. Sufferers experience painful cramps, bloating, diarrhoea and constipation, which can last for weeks or months at a time. There is currently no cure, but certain medications or dietary changes can help ease the symptoms.

There are several more traditional theories for the cause of the disorder, including abnormalities in the gut microbiome, miscommunication between the gut and the brain, or issues with the movement of muscles within the gastrointestinal tract. But Spiegel's gravity hypothesis adds another idea to the mix.

"As long as there's been life on Earth, from the earliest organisms to *Homo sapiens*, gravity has relentlessly shaped everything on the planet," said Spiegel. "Our body systems are constantly pulled downward. If these systems cannot manage the drag of gravity, then it can cause issues like pain, cramping, light-headedness, sweating, rapid heartbeat and back issues – all symptoms seen with IBS. It can even contribute to bacterial overgrowth in the gut, a problem also linked to IBS."

According to Spiegel, gravity can cause our internal organs to shift downward from their proper position. Some people are less able to cope with its pull than others, due to conditions such as spinal problems that cause the diaphragm to sag down or the belly to bulge.

Issues such as these could potentially trigger complications with the movement of muscles in the gastrointestinal tract, or even bacterial growth within the gut. This could also explain why physical therapy and exercise can often help ease the symptoms of IBS by strengthening the body's support structures.

"The body evolved to hoist this load with a set of support structures. If these systems fail, then IBS symptoms can occur along with musculoskeletal problems," said Spiegel.

Researchers at Cedars-Sinai now plan to investigate the theory further so they can look into the development of potential treatments.

"This hypothesis is very provocative, but the best thing about it is that it is testable," said Prof Shelly Lu, a gastroenterologist at Cedars-Sinai.

"If proved correct, it is a major paradigm shift in the way we think about IBS and possibly [its] treatment as well."

ALAMY, NASA/JPL-CALTECH

SPACE

IT IS UNLIKELY THAT THERE ARE ALIENS ON VENUS

Data collected by NASA's SOFIA observatory overturns previous findings that phosphine gas, a potential sign of microbial life, is present in the planet's atmosphere

An analysis of data collected by NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) has turned up no evidence of phosphine in Venus's atmosphere.

The NASA researchers were following up on the detection of phosphine by Japan's Akatsuki satellite back in 2020. At the time, the discovery got astronomers excited, as phosphine is considered to be a sign of life. This is because phosphine is unlikely to arise from chemical processes on worlds such as Venus, but is known to be produced by microbial life in bogs, swamps and marshes on Earth.

"Phosphine is a relatively simple chemical compound – it's just a phosphorus atom with three hydrogens – so you would think that would be fairly easy to produce. But on Venus, it's not obvious how it could be made," said Martin Cordiner, a researcher in astrochemistry and planetary science at NASA's Goddard Space Flight Center, Maryland.

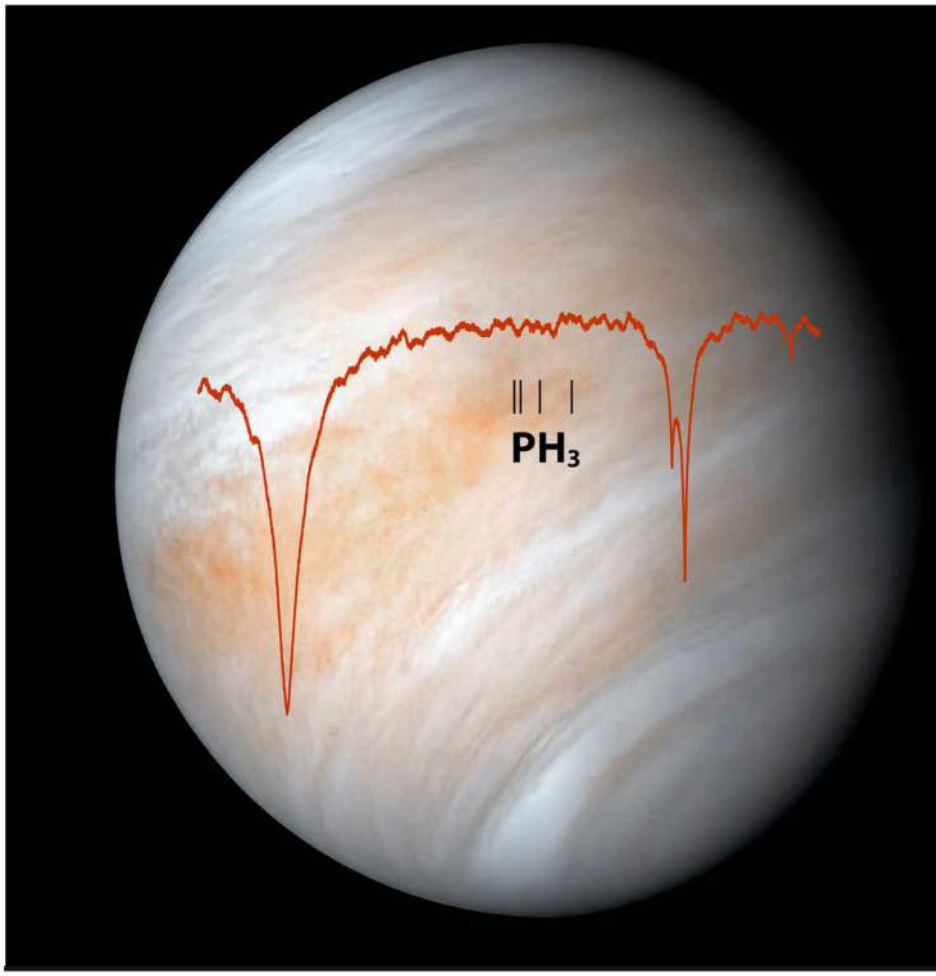
SOFIA was a telescope mounted on a Boeing 474 that was recently retired from service. It was positioned in orbit around 13km high in the Earth's stratosphere, putting it above 99 per cent of the atmosphere's infrared-blocking effects. This allowed astronomers to study the Solar System in ways not possible with ground-based telescopes.

The data analysed in the study were collected during observations of Venus's atmosphere over the course of three flights in November 2021. The SOFIA telescope's high resolution allowed it to scan for traces of phosphine around 75 to 110km above the entirety of the planet's surface – the same region as the original 2020 finding. However, no sign of the compound was found.

The new research complements data taken from other experiments carried out since 2020 that all point to phosphine not existing anywhere in Venus's atmosphere, from the equator to the poles.

Many aspects of Venus's atmosphere continue to puzzle scientists, and further discoveries may be made with NASA's VERITAS and DAVINCI missions, slated for launch in the late-2020s.

BELOW The spectral data from SOFIA overlain on top of this image of Venus. If a significant amount of phosphine were present in the planet's atmosphere, there would be dips in the graph at the four locations labelled PH_3



VENUS

475°C

Venus is the hottest planet in the Solar System with the surface temperature reaching around 475°C – hot enough to melt lead.

12,100KM

Venus has a diameter of 12,100km, making it slightly smaller than Earth.

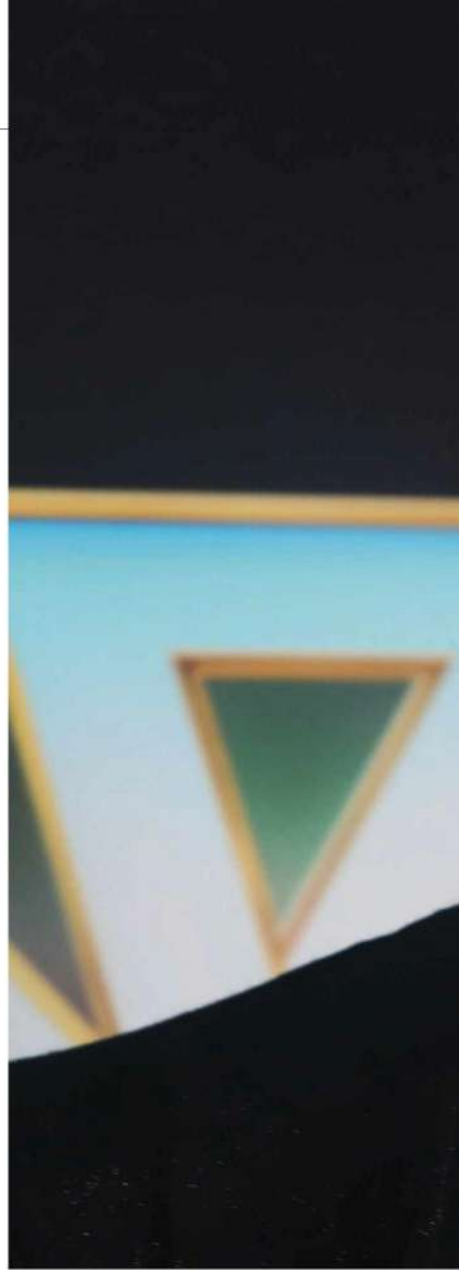
1,600

The planet's surface is peppered with volcanoes, around 1,600 in total. Scientists suspect four of these may be active: Maat Mons, Ozza Mons, Sapas Mons and Idunn Mons.

PRIMER

GENETIC TESTING

What can it tell us about our future health risks, and should we all be getting tested?



Actor Chris Hemsworth, who you might know as Thor in the Marvel Cinematic Universe, recently announced that he was taking a break from the limelight after carrying out a genetic test that highlighted he had a heightened risk of developing Alzheimer's disease. To find out whether we all ought to be considering testing ourselves, we spoke to Sir Peter Donnelly, CEO and co-founder of Genomics PLC, and emeritus professor of statistical science at the University of Oxford, about what genetic screening can tell us about our health.

WHAT HAPPENS WHEN SOMEONE TAKES A GENETIC TEST?

Usually, the test would involve taking a biological sample from the individual. Typically, that's either a blood sample, or a saliva sample. Then the sample would be sent to a laboratory, which would extract the DNA and then analyse it for the piece of genetic information that the test is trying to find.

WHAT IS DNA?

DNA is the chemical material that contains all of the information our cells use to do their stuff – to make the proteins that allow them to function, and to build up tissues and organs. We get one copy of our DNA from our mother and one from our father. The totality of the DNA is called our genome – that's just a word for all of the DNA.

DNA itself is a long chemical made up of different components. You can think of it as a long list and at each position there's one of four possibilities that happen to start with letters, A, G, C or T. In total we get three billion letters of DNA from our mother and three billion letters of DNA from our father. In every cell in our bodies, each of us has six billion letters.

WHAT IS A GENE?

A gene is a piece of our DNA where the letters contain explicit instructions that help our cells make a protein. They can differ in length.

A gene might be just a few hundred or thousand DNA letters long, but some genes are much longer. If we look at the totality of our DNA, only about 1 per cent of it is the genes. The rest used to be called 'junk DNA' before we understood what it was doing.

We now understand that it contains other information. For example, information that tells a particular gene when it should be making a protein. All of our cells have all of our genes. There might be a gene that makes a protein that's really important in the retina, but you absolutely don't need that protein in your tongue. And so there's instructions in the DNA that will be able to tell that gene, 'I want you to make this protein if you're sitting in a retina, but not if you're sitting in the tongue.'

HOW BIG AN INFLUENCE CAN A SINGLE GENE HAVE ON OUR BODIES?

We've got about 20,000 genes in total. In Chris Hemsworth's case, he's been talking about one particular gene. We know some things about what that gene does, but there are many mysteries – as there are with lots of human biology. We all have two copies of that gene, one from our mother and one from our father. The issue is that there can be slight differences between the copies. Lots of these differences don't have any effect at all, but some of them can have consequences and sometimes those consequences can be really severe. In conditions like cystic fibrosis, for example, where if you inherit a mutated copy of a gene that doesn't work the way it's meant to, you can end up getting really sick. Sometimes, if you have one copy of a gene that doesn't work, you're fine. For example, if the one from your mother doesn't work, but the one from your father is fine.

HEMSWORTH HAS BEEN TOLD HE'S AROUND 10 TIMES MORE LIKELY TO DEVELOP ALZHEIMER'S DUE TO THIS GENETIC FACTOR. HOW SIGNIFICANT IS THAT?

There are some diseases where if you inherit the genetic change, you will get sick. There are other examples, and this is one of those, where if you inherit a particular genetic change, you can be

GETTY IMAGES

A genetic test taken for a TV programme revealed the actor Chris Hemsworth has a higher risk of developing Alzheimer's disease

"In Hemsworth's case, we're talking about one particular gene. We know some things about what that gene does, but there are many mysteries"

more likely – sometimes quite a bit more likely – to develop the disease.

For most of the common conditions, such as heart disease, diabetes and many of the common cancers, genetics is a big part of the risk. But it's not just one change or two changes; it's millions of positions that each contribute a tiny bit to that risk. So Hemsworth's example is in the middle, where he's probably about 10 times more likely to develop disease. And although we're all very aware of diseases like Alzheimer's, it's quite rare. So there's a big difference between relative risk, which is how much more likely you are to get the disease than someone else, and absolute risk, which is about whether you'll actually get it. So the important point is it doesn't determine that he will or won't get the disease. It just increases the risk for him.

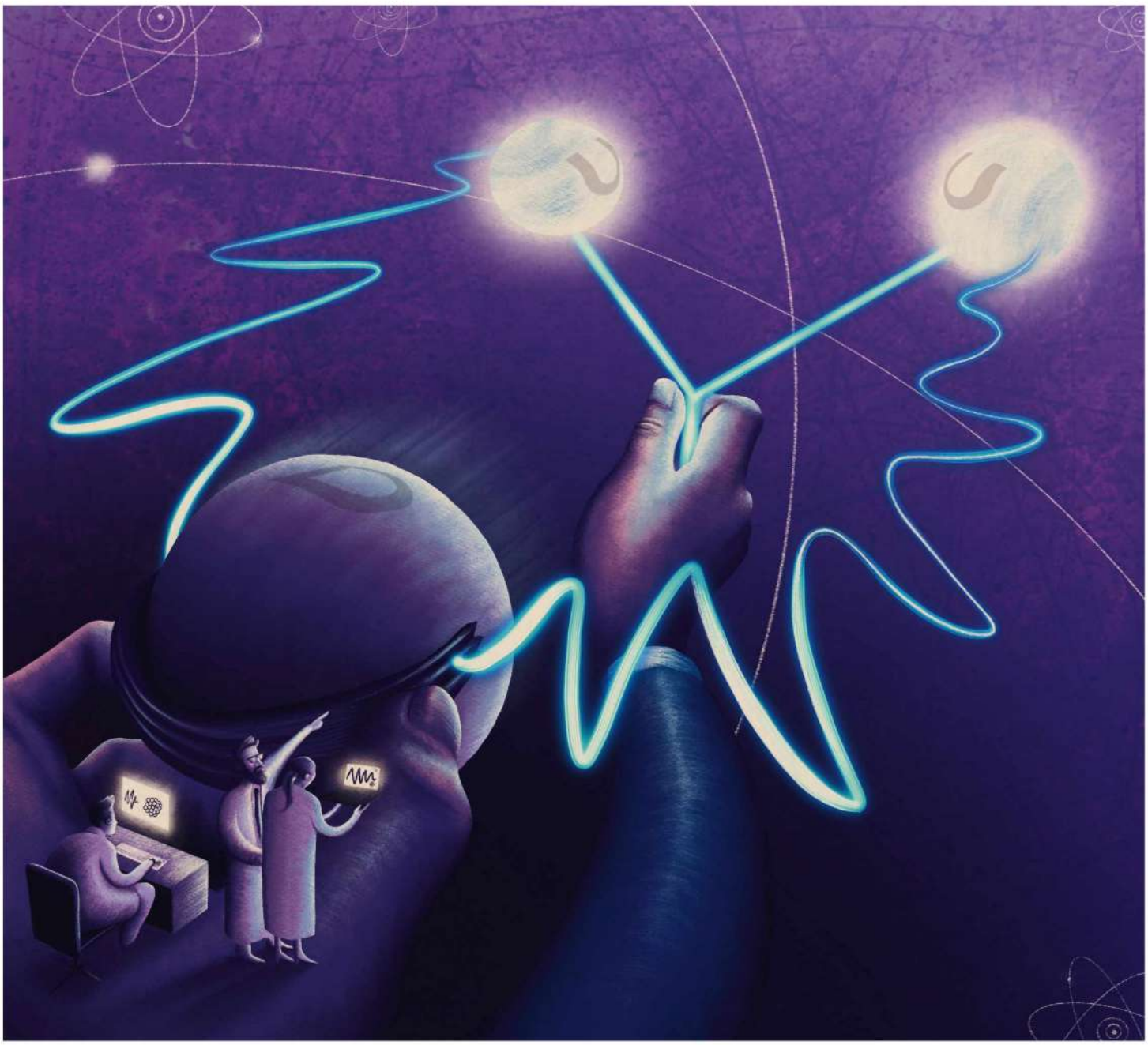
WHAT WOULD YOU SAY TO PEOPLE WHO WOULD RATHER NOT KNOW ABOUT THEIR POTENTIAL GENETIC RISK FACTORS?

It depends on the disease and on how big the impact is. In the case of Alzheimer's disease, the gene that was checked for Hemsworth is called APOE and it has quite a big impact on his risk of getting the disease. At the moment, there's not much you can do about it, so I think different people will take different views. Some would rather know and some would rather not know, and that's absolutely up to the individual. But I think Alzheimer's research is progressing really quickly. So it might well be the case that, before too long, there might be things you could do and drugs you could take to help reduce the risk or slow its progression. I think that it's a slightly different question for different diseases.

WILL WE EVER SEE A DAY WHERE WE HAVE ENTIRE POPULATIONS ROUTINELY HAVING GENETIC TESTS LIKE THESE?

I think that will happen. First of all, it should be up to the individual. No one should be forcing people to have tests like this. But for most common diseases, genetics is a risk factor and if we knew about it, instead of just saying: 'here are the 10 or 20 diseases you should be most worried about and here's some generic advice', we could be saying: 'in your case, you're at particularly high risk of heart disease'. We can actually tell you this when you're in your 20s, so you should work even harder on diet and lifestyle, or maybe it would be appropriate to go on drugs to reduce your cholesterol a bit earlier in life. We could do that because we have that special information about you.

SIR PETER DONNELLY
Peter is an emeritus professor of statistical science and director of the Wellcome Trust Centre for Human Genetics at the University of Oxford. He is also the CEO of Genomics PLC.



COMMENT

WE STILL HAVE A LOT TO LEARN ABOUT THE PROTON

Physicists investigating the subatomic particle's properties quickly find themselves going down a rabbit hole of complexity

A proton should be one of the simplest objects in physics. It's a basic building block of all atoms, or, alternatively, the simplest possible atom all by itself, since hydrogen (one positively charged proton plus one negatively charged electron) is still hydrogen when it's ionised. Most of the atoms in the Universe are hydrogen, as are most of the atoms in your body. In fact, since electrons are tiny and weigh very little, it's straightforward to conclude that you are mostly, specifically, protons.

Given all this, you'd think physicists would understand protons very well by now. You would be wrong.

If you ask your physics teacher what protons are made of, they'll likely tell you protons are made of three smaller particles called quarks. Quarks come in six different types, or 'flavours': up, down, charm, strange, top, and bottom (they were named in the 1960s and 1970s), with up and down quarks combining to make protons and neutrons.

Since the up quark has a charge of +2/3 and the down quark has a charge of -1/3, the sums all work out if a +1-charged proton is two ups and a down (2/3 + 2/3 - 1/3 = +1) and a neutral neutron is two downs and an up (-1/3 -1/3 + 2/3 = 0).

So far, so good.

But while the charges add up perfectly, the masses don't. In particle physics, we usually measure mass in terms of energy (interchangeable via that old standard, $E = mc^2$), and for this purpose we'll use units of MeV, for Mega-electron-volts.

If you look up quark masses online you'll find that the mass of an up quark is around 2MeV while a down quark is close to 5MeV. But those same sources will tell you the mass of a proton is a whopping 938MeV. Our sums are off by about 99 per cent.

Before we panic, we can ask, what else is in the proton? And we have a convenient answer: gluons! Gluons are the aptly named particles that carry the strong nuclear force, just as photons carry light – the electromagnetic force. Gluons are in the proton to hold the quarks together, so surely they must contribute something. But gluons have something else in common with photons: they're entirely massless.

So how do we build a proton that weighs 938MeV out of three quarks that weigh a total of 9MeV and a handful of particles with no mass at all? The answer is even more complicated than you might imagine. For one thing, it's not quite right to say there are three quarks in a proton. Really, a proton is a roiling quantum sea of an uncountable number of quarks, antiquarks and gluons, constantly shifting in and out of existence by transforming into one another. And those ethereal particles zipping around inside the proton carry kinetic energy, which, via $E = mc^2$, gets us about 60 per cent of the 938MeV that we need.

The final piece comes from the energy of the strong nuclear force itself. The quarks are not merely bound by the strong force, but confined. This is different from gravity or electromagnetism, where the more separation you get, the weaker the attraction – you can, with enough effort, pull magnets apart, or accelerate a rocket away from Earth. But the strong force will just keep pulling.

There's so much energy tied up in the force itself that even if you manage to pull two bound quarks apart hard enough to overcome their strong force attraction, the energy you have to put in to break that bond will spontaneously create two new quarks, one bound to each of the ones you just separated. Quarks do NOT like to be separated.

"So how do we build a proton that weighs 938MeV out of three quarks that weigh a total of 9MeV, and a handful of particles with no mass at all? The answer is even more complicated than you might imagine"

The energy inherent in quark confinement solves the proton mass puzzle, but the calculations of exactly how this term arises, and what its magnitude is, are incredibly complex, and the more you look into them, the more complex they become. Recent experiments have shown that protons can sometimes be observed containing charm quarks, which is particularly surprising, since charm quarks are more massive than protons are.

Measurements of the proton's size have been controversial for decades: you get different answers depending on whether you measure it by scattering electrons off the proton or by watching the electron in a hydrogen atom pass right through the proton, which is a thing it does routinely, just on a normal day, because nothing at that scale is sacred at all.

With new, advanced computational techniques, we're making progress. And the measurements are already incredibly precise. If we can unlock the mysteries of this most basic of atomic building blocks, we'll be closer to understanding the fundamental laws that govern reality itself. Or maybe we'll discover something even more bizarre hiding within it.

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

NERISSA ESCANLAR ILLUSTRATION: MATT HOLLAND

COMMENT

CAN ARTIFICIAL AGENTS BE TRUSTED?

AI systems can now generate and use language that feels like a real conversation. But to whose benefit?

Imagine being able to chat with an artificial intelligence (AI) about anything. What if you could discuss last night's game, get relationship advice, or have a deep philosophical debate with the virtual assistant on your kitchen counter? Large language models – AIs capable of this level of communication – being developed by companies such as OpenAI, Google and Meta are advancing quickly enough to make this our new reality. But can we trust what artificial agents have to say?

There are many reasons to embrace conversational AI. The potential uses in health, education, research, and commercial spaces are mind-boggling. Virtual characters can't replace human contact, but mental health research suggests that having something to talk to, whether real or not, can help people. Besides, it's fun to banter with an artificial agent that can access all of the knowledge on the internet.

"We need to ask who creates and owns large language models, who deploys the devices that use them, and whom this harms or benefits"

But conversational agents also raise ethical issues. Transparency is one: people may want to know whether they're talking to a human or a machine. This makes sense, but it's probably also fairly easy to address in contexts where it matters. The bigger problem with these systems is that we trust them more than we should.

As conversational agents become more compelling, will we rely on them for information? We may even grow fond of the artificial characters in our daily lives. There's a large body of research in human-computer and human-robot interaction which shows that people will reciprocate social gestures, disclose personal information, and are even willing to shift their beliefs or behaviour for an artificial agent. This kind of social trust makes us vulnerable to emotional persuasion and requires careful design, as well as rules to ensure that these systems aren't used against people.

A chatbot may, for instance, blurt out racist terms, provide false health information, or instruct your child to touch a live electrical plug with a coin – all of which have happened. The newest language models are trained on vast amounts of text found on the internet, including toxic and misleading content. These models also use neural networks, which means that instead of following rules ('if the input is x, respond y'), they create an output by learning from a mishmash of examples in a way that is harder to understand or control.

As it becomes more difficult to anticipate a language model's responses, there's more risk of unintended consequences. For example, if people ask their home assistant how to deal with a medical emergency, invest their money, or whether it's okay to be gay, the wrong kinds of answers can be harmful.

The information that people may share with their devices is also troubling. When computer scientist Joseph Weizenbaum created a simple chatbot called ELIZA in the 1960s, he was surprised to find that people would give it personal information that they wouldn't disclose to him, even though he had access to the chat data. Similarly, people may tell artificial agents their secrets, without thinking about whether and how companies may collect and mine that information.

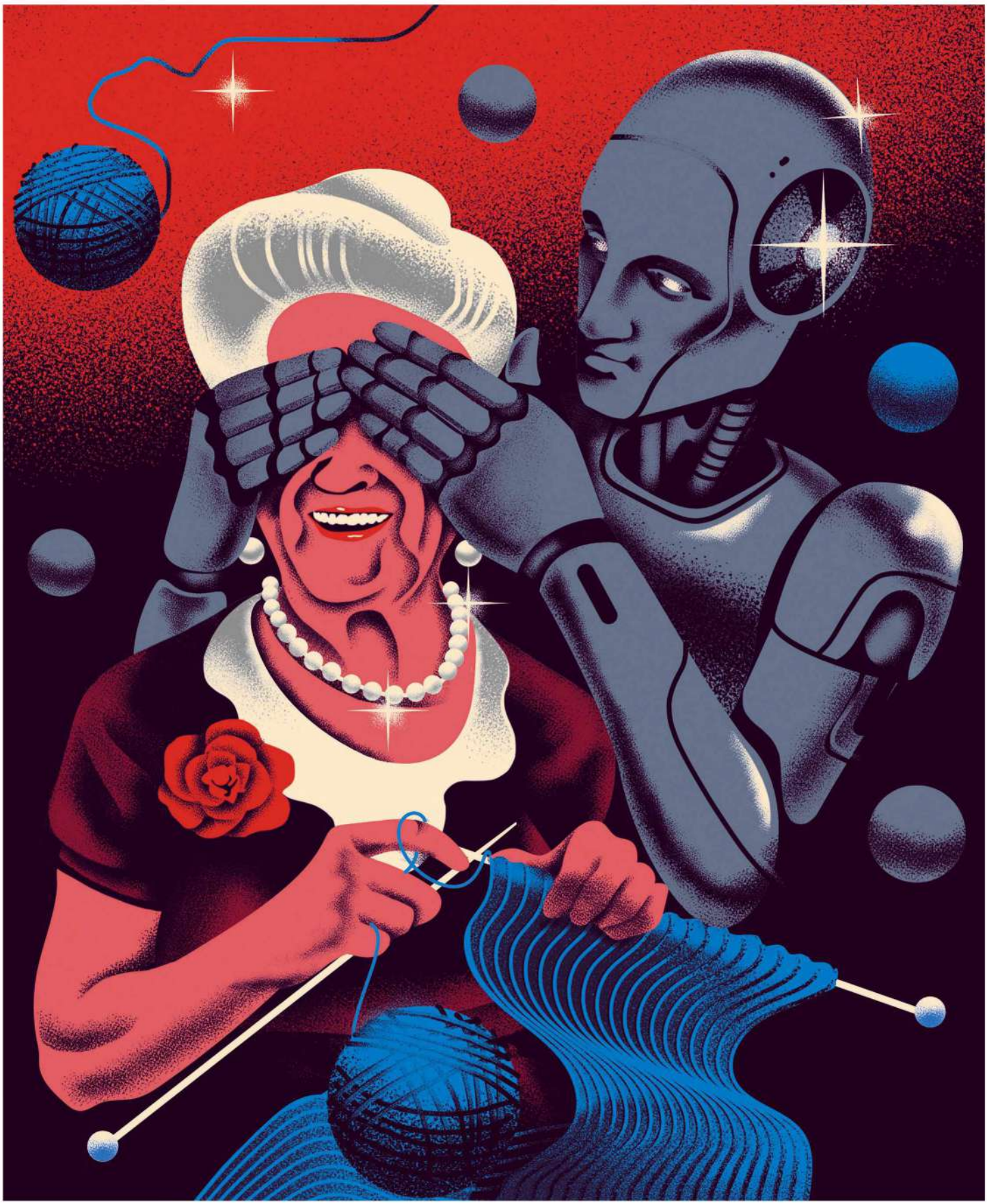
We need to ask who creates and owns large language models, who deploys the devices that use them, and whom this harms or benefits. Personal information that people reveal in conversation can be used for and against them. The idea of having an artificial agent who remembers things about you is appealing, but it could also allow others to manipulate you and your loved ones. One day, your home assistant could alert you to a deal on a car you can't really afford, at a time when it knows you're emotionally most likely to buy it. Imagine if it gave you selective political information, or asked for a software upgrade it knows you're willing to spend money on.

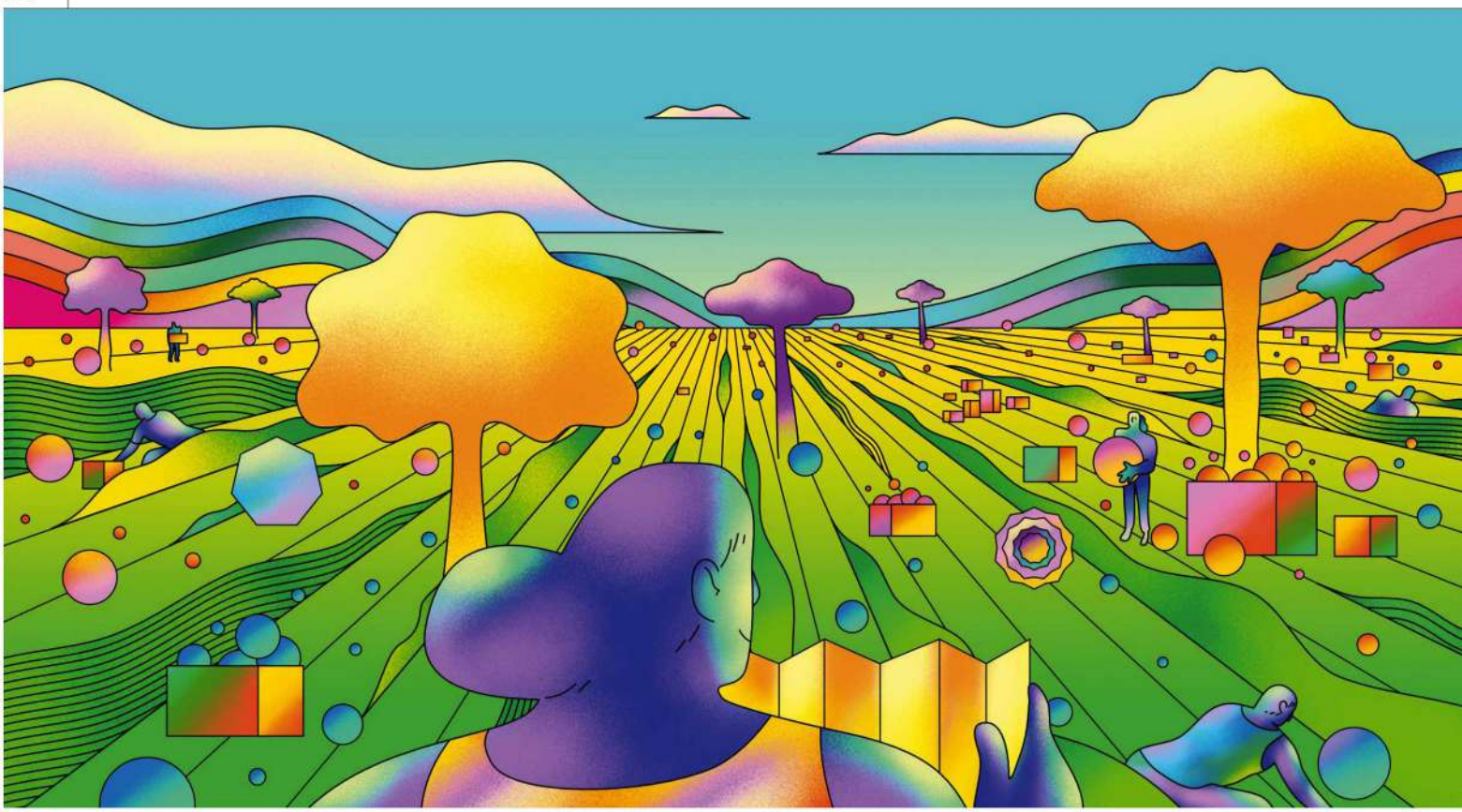
If that sounds dystopian, consider that we're almost there. Last week, the Amazon Echo in my kitchen tried to sell my kids an 'extreme fart package'. Advertisers invest massive amounts every year to reach children and teenagers, and recent research I collaborated on with MIT PhD students Anastasia Ostrowski and Daniella DiPaola indicates that kids are confused about the role of companies when an artificial agent advertises products to them – a very near-future consumer protection issue.

It's wild to think that my kids will not remember a time before we could talk to machines. As we enter this reality, it's both exciting and concerning to imagine the different paths this era could take. As people begin to forge relationships with, and perhaps even demand rights for, artificial agents, we need to ensure that this technology is designed and used responsibly. After all, humanity deserves protection, too.

DR KATE DARLING
(@grok_)
Kate is a research scientist at the MIT Media Lab, studying human-robot interaction. Her book is The New Breed *(£20, Penguin).*

ILLUSTRATION: VALENTIN TKACH





COMMENT

CLIMATE CHANGE IS ALREADY HAVING AN EFFECT... ON OUR MENTAL WELLBEING

People's growing anxiety about the future of the planet is becoming increasingly obvious, but it's not an entirely bad thing

DR JULIA SHAW
(@drjuliashaw)
Julia is a psychological scientist at University College London, the author of multiple best-selling books, and the co-host of the hit podcast Bad People *on BBC Sounds.*

How worried are you about environmental issues? If thinking about climate change and biodiversity loss stresses you out, you're not alone. Psychologists are trying to understand this feeling – referred to as eco-anxiety – and they're finding that this worry may be essential for our fight to save the planet.

In late 2021, Australian applied psychologist Teaghan Hogg and colleagues proposed a new scale to help us measure eco-anxiety: the Hogg Eco-Anxiety Scale. It uses 13 questions to capture our complex feelings about the environment.

The scale asks about negative emotions like feeling nervous, on edge or afraid about environmental issues, including global warming, ecological degradation, resource depletion, species extinction, the hole in the ozone layer, pollution of the oceans, and deforestation. The scale also measures whether we ruminate on these issues, to see if we're unable to stop thinking about climate change or losses to the environment.

It also asks how these thoughts and feelings change our behaviour, such as whether they lead to difficulty sleeping, working, or enjoying social situations, and how responsible we feel for the crises we're facing – for instance, whether we feel anxious about the problems our personal behaviours are causing for the planet, or that our individual actions will do little to solve them.

If you just thought, "wow, that's me most days", then you probably have high eco-anxiety. This is common around the world and across all ages, but it seems to be the most pronounced among young people.

In 2022, researchers working with UNICEF, the United Nations Children's Fund, published the first large-scale international survey on climate anxiety in children and young people. They surveyed 10,000 people aged between 16 and 25, across 10 countries (Australia, Brazil, Finland, France, India, Nigeria, Portugal, the Philippines, the UK and the USA). They found that 59 per cent of people were very or extremely worried about climate change, and 84 per cent were at least moderately worried.

Tapping directly into facets of eco-anxiety, the UNICEF researchers also found that half of the children and young people reported feeling sad,

ILLUSTRATION: SCOTT BALMER

“The climate crisis is a very real danger so it’s good that our brains are trying to make us pay attention and do something about it”

anxious, angry, powerless, helpless and guilty about environmental issues. More than 45 per cent said their negative feelings about climate change affected their daily life, with fears about the future dominating their thoughts along with deep feelings of betrayal from governments.

This is a potential problem for mental health. Constantly feeling anxious and worried about the climate can lead to chronic stress in childhood, which can have long-lasting consequences.

So are young people in danger of becoming mentally ill because of the constant stress these issues have on them? In a review of research on the health consequences of eco-anxiety published in 2022, a team of Spanish and Brazilian researchers found that it is associated with depression, anxiety, stress, insomnia, lower self-referred mental health, impairment to memory and attention, and a reluctance to have children.

This doesn’t mean that today’s young people are all going to be crippled by eco-anxiety. But it does mean that we need to keep an eye on the psychological effects that climate change is having.

There is a positive side to eco-anxiety, though, as it has been linked with pro-environmental action and climate activism. It’s because of this that some researchers have argued that, overall, eco-anxiety is a good thing because it’s a practical anxiety.

Anxiety is the body’s way of telling us that we may be in danger. This anxiety leads us to try and figure out what that threat to us is, driving us to find more information and figure out a solution to make us safe. The climate crisis is a very real danger, so it’s good that our brains are trying to make us pay attention and do something about it, because that’s how we counter this threat.

The researchers who examined the link between eco-anxiety and health found that pro-environmental action could buffer against this anxiety evolving into depression. Which is to say that if you’re experiencing eco-anxiety, then simply carrying out behaviour that is good for the planet – like recycling, petitioning local government officials, joining a march, or taking trains instead of planes – might also do wonders for your mental health.

BBC SOUNDS

Listen to Dr Julia Shaw on the *Bad People* podcast, available on BBC Sounds.

PCSPECIALIST

YOUR PC. YOUR WAY.

CUSTOM BUILT TO YOUR SPEC

EASY TO USE CONFIGURATOR

CUSTOM PCS & LAPTOPS

AWARD-WINNING SYSTEMS

GET AN EXCLUSIVE **£15 DISCOUNT** WITH BBC SCIENCE FOCUS USING CODE: **BBF22**

COBALT SUPREME

- Intel® Core™ i5-13600K
- GIGABYTE Z690 AORUS Elite AX
- NVIDIA® GeForce RTX 3060 Ti
- 32GB Corsair VENGEANCE 4800MHz RAM
- 1TB SOLIDIGM P41+ M.2 SSD
- Windows 11 Home

Configure from

£1,820.00*

QUANTUM ELITE

- AMD Ryzen 9 7950X
- ASUS® ROG Crosshair X670E HERO
- 24GB NVIDIA GEFORCE RTX 4090
- 64GB Corsair DOMINATOR PLATINUM 5600MHz RAM
- 1TB SAMSUNG 980 PRO M.2 SSD
- Windows 11 Home

Configure from

£4,285.00*

ARC NOVA

- Intel® Core™ i5-12400F
- ASUS® TUF Gaming B660M-PLUS WIFI D4
- 16GB PCS PRO DDR4 2666MHz RAM
- 8GB INTEL ARC A750
- 1TB SOLIDIGM P41+ M.2 SSD
- Windows 11 Home

Configure from

£1,220.00*

CONFIGURE YOURS TODAY

WWW.PCSPECIALIST.CO.UK

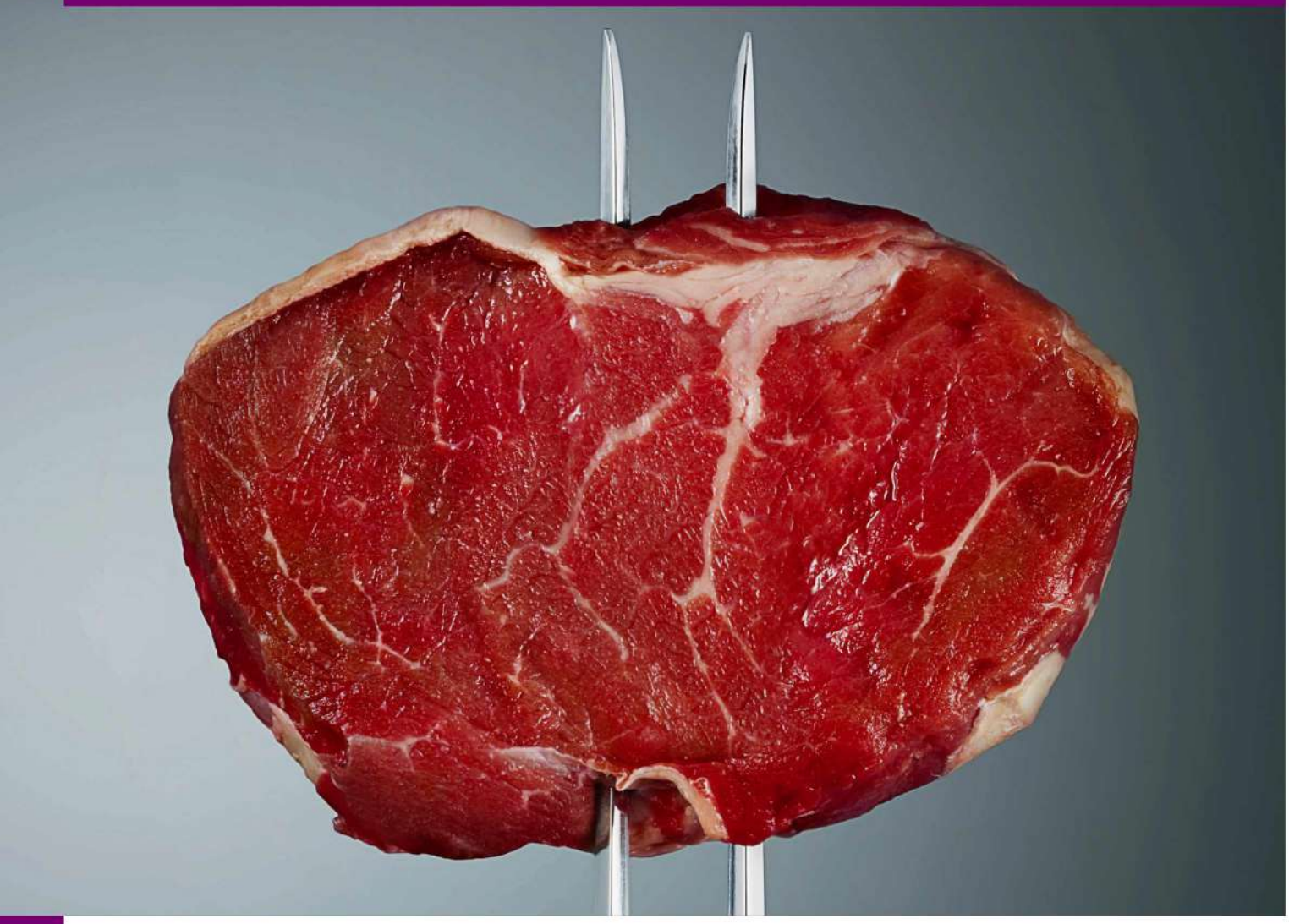
PCSpecialist

*Prices are including VAT and are correct at time of printing, but subject to change. Images are for illustration purposes only, components may differ in aesthetics and brand.

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

The carnivore diet | Social anxiety | Food aversions



REVIEW

THE CARNIVORE DIET: CAN EATING A MEAT-ONLY MENU BE GOOD FOR YOUR HEALTH?

The meat-only diet has gone viral on social media, with its proponents claiming that humans evolved to exist on animal protein alone

"Side effects are similar to those reported for the ketogenic diet: bad breath, constipation, diarrhoea, headaches, dehydration"

BBC *Visit the BBC's* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

You've probably heard of the ketogenic diet and you may have heard of the paleo diet, but have you heard of the carnivore diet? This emerging diet trend takes low-carbohydrate diets to a new extreme.

The carnivore diet excludes all plant foods; only foods derived from animals are consumed, including meat, fish, animal fats (lard and ghee, for example) and low-lactose dairy products. So, breakfast might be eggs and bacon with cream, lunch could be cheese-topped meatballs (no herbs added) with chicken breast and, finally, roast beef and salmon for dinner.

Advocates of the carnivore diet contend that plant toxins and residual pesticides used in plant food production are harming our health. They claim that starchy foods only became a major part of the human diet with the agricultural revolution. Finally, it's proposed that eliminating all plant foods is the best way to go sugar-free for weight control and metabolic health.

Authors of carnivore diet books tend to frame their subject as the answer to the problem of obesity and non-communicable chronic diseases, and often claim that decades of nutritional science research have culminated in flawed dietary recommendations. Most of these authors draw on the argument that *Homo sapiens* evolved to hunt for meat and fish, and that plant-eating was only a back-up plan for times of animal food scarcity.

WHAT COULD YOU EXPECT IF YOU CONSUMED ONLY ANIMAL-SOURCED FOODS FOR A SIGNIFICANT PERIOD?

Unfortunately, there's no scientific evidence available on the health impact of excluding all plant foods from the diet. The only available sources of information are anecdotal reports and testimonials reporting better weight management, improved heart and metabolic health, superior cognitive function and lower inflammation, as well as better digestive function and resolution of auto-immune diseases.

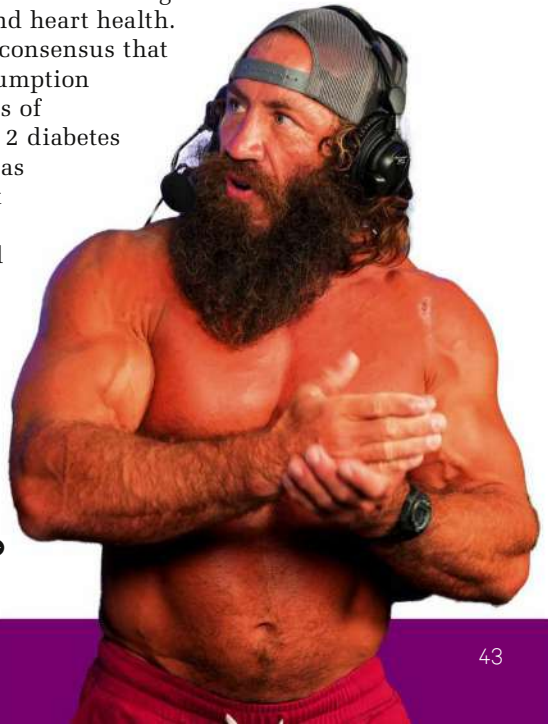
Side effects are similar to those reported for the ketogenic diet: bad breath, constipation, diarrhoea, headaches, dehydration and other symptoms associated with being in a state of ketosis (when the body has used up all its glycogen stores and breaks down fat into ketone bodies that can be used as a source of energy, instead of glucose). These side effects may eventually subside as the body adapts to the diet after about a month.

WHAT ARE THE NUTRITIONAL BENEFITS OF THE CARNIVORE DIET?

Meat is an excellent source of high-quality protein, iron, zinc, selenium, vitamin D, vitamin B6 and vitamin B12. Fish contributes high-quality protein, omega-3 fatty acids, vitamin D, selenium and iodine. Dairy foods are also rich in high-quality protein, as well as calcium, iodine and B vitamins. The UK dietary guidelines, embodied in the NHS's Eatwell Guide, recommend dairy foods, lean meats (no more than 70g per day of red or processed meat) and two portions of fish per week (one of which should be oily fish).

However, the Eatwell Guide also recommends consuming at least five 80g portions of fruits and vegetables per day, and that a third of what we eat should be wholegrain and higher-fibre starchy foods. Cutting out fruits, vegetables, nuts, seeds and wholegrains on the carnivore diet would mean zero fibre intake, with unknown long-term consequences for gut and heart health. In fact, there's strong global consensus that increased dietary fibre consumption is associated with lower risks of cardiovascular disease, type 2 diabetes and colorectal cancer, whereas high red and processed-meat consumption increases risk.

Evidence from randomised controlled trials shows that plant foods rich in soluble fibre can lower blood low-density lipoprotein (LDL) cholesterol and triglyceride concentrations, decrease the rate of progression of atherosclerosis – fatty lesions that can damage and block arteries, causing ➔



BELOW Brian 'Liver King' Johnson built a social media following by promoting his version of the carnivore diet, called 'the primal diet'

GETTY IMAGES, ALAMY

ABOVE Fibre-rich plant foods help decrease the build up of fatty lesions that can damage and block arteries

coronary heart disease and stroke. Conversely, fatty meats and butter can raise LDL cholesterol. Plant foods are also rich in potassium, vitamin C, folate and other micronutrients – all essential for health and derived mainly from fruit and veg.

Additionally, we know that healthy plant-based diets are associated with more diverse and beneficial gut microbiome profiles, resulting in microbial fermentation products from fibre and non-nutrient bioactive compounds that may reduce inflammation.

WHAT'S SO APPEALING ABOUT THE CARNIVORE DIET?

Supporters of the carnivore diet often claim that subsisting entirely, or nearly entirely, on animal-sourced foods is close to the natural human diet, aligned with what was eaten in early human history. But biological anthropologists would point out that the anatomy of our brains, teeth and intestines show that we evolved as resourceful and flexible omnivores who can adapt to varied environments to meet our nutritional needs from both animals and plants.

Collectively, we must accept that global food production needs a major shake-up if population nutritional needs are going to be met while also attempting to hold back climate change. Reducing meat consumption is an essential component of the move towards sustainable, healthy food systems. The carnivore diet flies in the face of this global mission for planetary health, for the sake of perceived personal gains. Regardless of the potential long-term harm to healthy life expectancy, this seems to be the ultimate selfish act.

by **DR WENDY HALL**

Wendy is a registered nutritional scientist and reader at King's College London. Her research focuses on the impact of diet on risk of cardiovascular disease and type 2 diabetes. She is Theme Leader for Nutrition and Optimum Life Course for the UK Nutrition Society.

ANALYSIS

SOCIAL ANXIETY: HOW TO DEFEAT THE DREAD OF PARTY SEASON

Christmas comes but once a year, and its many parties fill some with fear

As December draws to a close, so too does party season. Whether it's the office Christmas party, a Yuletide family get-together or New Year's Eve, the idea of socialising fills many people with dread. If all the parties over the festive period stressed you out, the first thing to say is you're not alone. Of course, there's a spectrum of severity, but feeling nervous about socialising is incredibly common.

SCIENCE PHOTO LIBRARY, GETTY IMAGES

ABOVE Look out for anyone who may be feeling left out and try to make it easier for them to feel included

"The simple truth is a lot of people are so wrapped up in their own worries that they're not judging you as closely as you might think"

The reason for this is the way we evolved. Throughout our ancestral history, humans needed to work in groups to stay alive. That's why we've developed instincts to care a lot about social stuff, why we're so concerned about things like reputation and status, and why we dread making a fool of ourselves or being left out.

But don't forget, social occasions are an opportunity, not just a threat – they're a chance to forge shared memories, bond and have fun together. So as an initial step towards alleviating your anxiety, try boosting your hopefulness about these events. For example, remind yourself of occasions – however rare they might be – when things went well and you had a fun time or you made new friends.

Next, from a practical perspective, one of the most effective ways to reduce your social anxiety is to be a little strategic and proactive. So rather than waiting for the obligations to roll in and letting them hang over you like a dark cloud, be clear about which ones you really want or need to go to.

If there are friends you'd love to go with, don't wait for them to ask you – reach out and make it happen (they'll probably be thrilled to hear from you). If you struggle with small talk, don't be afraid to do a little prep – get up to speed on the latest current affairs or sports news, so that you've got some material at hand to lighten those initial interactions.

If you're quiet by nature and don't socialise much during the rest of the year, it can be helpful to use so-called 'if-then plans' so that you don't freeze or feel overwhelmed when you first walk into the room. For instance: if I'm feeling stuck for conversation, then I'll ask the person next to me what they think of Elon Musk taking over Twitter; or, if I'm feeling left out, then I'll look for the friendliest-looking person or people in the room and ask them one question (such as, 'do you have any big plans for the New Year?').

There are some psychology findings that you might find comforting. One of my favourites is a study by psychologists at Washington University in St Louis that asked volunteers with social anxiety to rate the quality of their relationship with a given friend.

Then the researchers approached that named friend and asked them to rate the relationship too. The reassuring finding was that the named friends rated the friendships more positively than the volunteers with social anxiety – in other words, your friends probably like you more than you realise.

Here's another comforting study that led psychologists to propose something called the 'spotlight effect' (the way that we tend to think people are scrutinising us much more closely than they really are). It involved volunteers wearing an embarrassing item of clothing (at the time, around the year 2000, this was considered to be a Barry Manilow T-shirt) in a group setting and then estimating how many people in the room noticed it.

The volunteers massively overestimated how many people noticed their embarrassing attire; in reality, the others just weren't paying that much attention to them. Bear this in mind when you're agonising

You're not obliged to accept every invite. You're more likely to have a good time if you accept only those you want to attend

over what to wear or what to say. The simple truth is a lot of people are so wrapped up in their own worries that they're not judging you as closely as you might think.

Indeed, excessive self-focus is one of the main drivers of social anxiety. Constantly monitoring your own behaviour and utterances will fuel your nerves and, in worst-case scenarios, lead you to act more awkwardly. Anything you can do to try to get out of your head and focus your attention outwards ought to alleviate your anxiety. You could even give yourself another if-then plan to help with this: if I find myself being self-focused, then I'll make a conscious effort to listen to what someone is saying or look at what they're wearing.

Taking this further, why not set yourself a little goal to be on the lookout for anyone else at the party or dinner who seems uncomfortable or left out. There are bound to be people feeling that way and you could be the one to make their experience more positive.

Above all, remember that avoidance (either not going out or resorting to excess drink or drugs) never helps anxiety – it just fuels it. Like all challenges in life that we find difficult, socialising gets easier with practice. But don't expect too much of yourself either – pace yourself and do your best. Plan ahead and focus your attention on the other people you're there with, and who knows, you might even have a little fun along the way.

by **DR CHRISTIAN JARRETT**

Christian is a psychology and neuroscience writer. His latest book is Be Who You Want: Unlocking The Science Of Personality Change *(£14.99, Robinson).*

COMMENT

FOOD AVERSIONS: ARE THEY LEARNED OR GENETIC?

Ever wondered why you love some foods but can't bear the smell, let alone taste, of others?

There are some tastes that we're hard-wired to favour. One of those is sweetness. Not only does an early preference for sweetness help to ensure that babies are attracted to the slightly sweet taste of breastmilk, but our general preference for sweetness is understood to be an evolutionary adaptation, motivating us to seek out and consume (once rare) energy- and carbohydrate-rich foods. Sweetness may also have become a signal for safety, as there are hardly any naturally sweet foods that are toxic.

The bumps on your tongue, called papillae, also contain thousands of receptors for the other basic tastes: bitter, sour, umami (the rich, savoury taste of cheese, meat and mushrooms), salty, and the recently added oleogustus – which describes the unique taste of fat. Again, these tastes indicate the nutrient content and safety of a food.

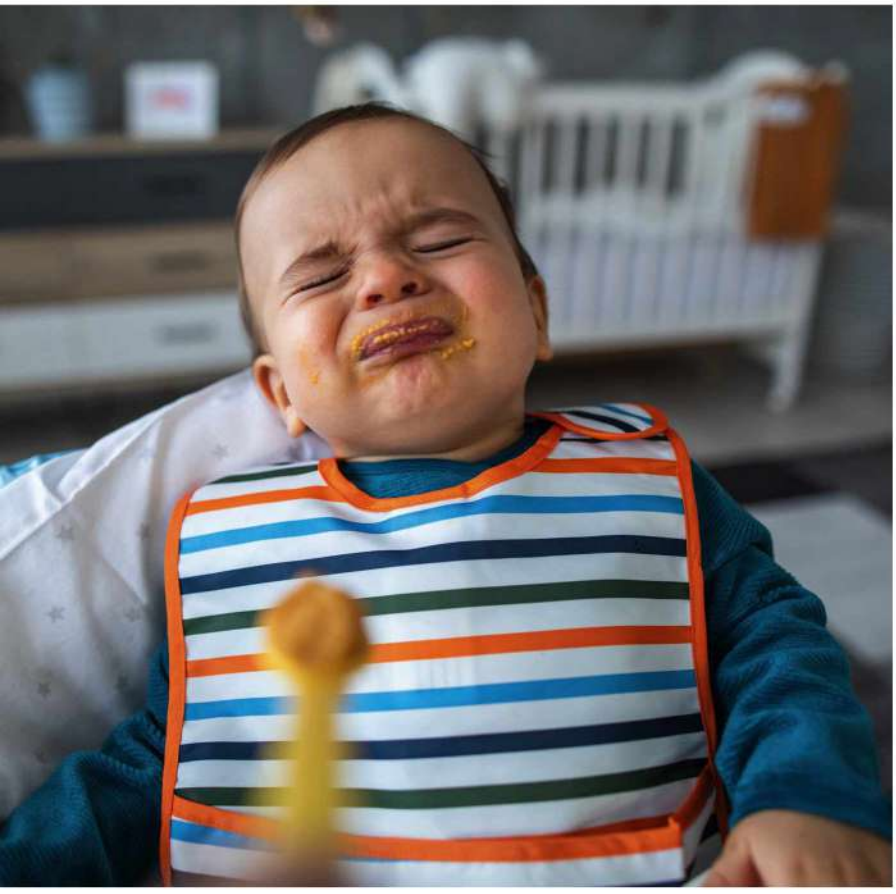
Mineral-rich foods taste salty. Not only are minerals important helpers for enzyme activity in the body, but nerves send their messages using sodium ions, making minerals essential for the proper function of your brain and nervous system. Like carbohydrates, fat is an important energy source. Umami indicates the presence of amino acids, the building blocks of proteins required for making and repairing cells and tissues, as well as for the production of neurotransmitters.

Conversely, we tend to find bitter and sour tastes aversive, particularly in childhood, which is a crucial protective adaptation because these tastes can indicate the presence of toxins. For example, a class of bitter-tasting compounds called alkaloids have psychoactive effects. Nicotine and cocaine are in this group, but so are caffeine and theobromine (found in chocolate). The heightened risk of toxicity or other harmful side effects is thought to be why babies are so much more sensitive to these tastes than adults. Our sensitivity to bitter tastes reduces over time, which is why babies can't stand the taste of coffee but many adults love the stuff.

Actually, that's not the only reason adults like coffee, because food preferences are not simply about flavour; they're also about sensation. If you are a regular coffee drinker, the likelihood is that you baulked at your very first sip. A few moments

GETTY IMAGES X2

"While many aversions are psychological, a few are genetically driven"



later, however, as the caffeine made its way to your brain, you might have experienced a pleasant feeling, one of mild euphoria or heightened alertness. These pleasurable sensations become encoded alongside the taste of the coffee. So part of the reason you like coffee is because of the feeling it provides.

And this offers another hint as to why we like some foods and not others: psychology. If a beloved grandmother always made you a walnut cake for your birthday as a child, the flavour of walnut cake (and perhaps also the texture and smell of toasted walnuts) will be associated for you, largely unconsciously, with fond memories and pleasing sensations. In a sense, every time you eat walnut cake as an adult, you elicit and neurologically relive those associations, meaning a big part of the enjoyment is in the memory.

ABOVE There may be strong psychological associations at the root of your dislike of certain foods

In contrast, if the first time you ate walnuts you became sick (perhaps because you were coming down with the flu), you might make a negative association with them. Essentially, your brain tagged walnuts as a risky food, making it difficult to even think about eating them. This aversive response can be powerful, persisting even when you know the food in question had nothing to do with the sickness.

So is there any chance of changing our food preferences? Yes and no. While many aversions are psychological, a few are genetically driven. If, for example, you're someone who hates coriander and think it tastes like soap, then it's possible you possess a variant of a gene that affects your sensitivity to certain naturally occurring chemicals in the herb. But most of our aversions are like the one mentioned above or culturally acquired. The difference between many of the things we like or dislike comes down to culture, for example, in some parts of the world, guinea pigs are beloved family pets; in others they're a delicious source of protein. What this means is that we learn to like the foods that we most frequently encounter and that are valued by those around us.

And this is good news if you have an aversion that you would like to overcome (to be clear, we're not talking about allergies or intolerances here). By trying small amounts of the food you're averse to repeatedly, and in a calm and relaxed state, you can learn to appreciate it. It can also be helpful to try the food cooked in different ways. So if you grew up hating boiled Brussels sprouts, try them shredded and stir-fried or roasted with garlic. It can also be good to challenge your beliefs about the food. Reading up about why sprouts are so good for you can help make you more willing to try them, and this willingness can help to nudge you over the line to acceptance.

For most things, a shift in attitude and repeated exposure can help to make a formerly hated food more palatable. **SF**

by **KIMBERLEY WILSON**
Kimberley is a chartered psychologist with an MSc in nutrition. She is the co-host of BBC Radio 4's Made Of Stronger Stuff. *Her book,* How To Build A Healthy Brain *(£16.99, Yellow Kite), is out now.*

CELEBRATING 60 YEARS OF *BBC WILDLIFE*

SPECIAL 60TH ANNIVERSARY OFFER

SAVE 60%

OFF A 2-YEAR SUBSCRIPTION PLUS WELCOME BUNDLE WORTH £50!

Get closer to nature next year with our special 60th anniversary *BBC Wildlife* magazine subscription offer

Visit **buysubscriptions.com/WL60FCA**

Call **03330 162 112**† QUOTE CODE **WL60FCA**

†Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 8am-8pm weekdays and 9am-1pm Saturdays. *Save 60% off a 2-year subscription + welcome bundle is available for UK subscribers only paying by Direct Debit. Please allow up to 28 days to receive your welcome bundle. Welcome bundle is available whilst stocks last. Our Media Ltd reserves the right to send an alternative welcome treat of similar value. *BBC Wildlife* is published 13 times a year. Your subscription will start with the next available issue. Offer ends 31st January 2023.

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

ANALYSIS

GOOGLE PIXEL WATCH

Fancy slapping this high-tech timepiece on your wrist? **p50**

FIVE OF THE BEST

ELECTRIC BIKES

Bicycles that put the power in pedal power **p52**

NEW TECH

IDEAS WE LIKE

The gadgets we're lusting after this month **p54**

Can Google's Pixel Watch compete with Apple and Samsung? Find out on p50

1895 The year the first patent for an electric bike was filed.

130 million
The estimated number of electric bike sales globally in 2023.

How much faster the average journey on an electric bike is, compared to a traditional bike.

REVIEW

Google Pixel Watch: plenty of style, slightly less substance

Alex Hughes straps on Google's first smartwatch to see if it has a future in wearables

Everything points to the idea that Google should be a dominating force in the world of wearables. Google owns the massive wearable brand Fitbit; it's the maker of Wear OS, the software that most Android smartwatches run on; and it's Google, one of the biggest names in technology! So it's surprising that Google hasn't made a smartwatch… until now.

The Google Pixel Watch is the brand's first smartwatch. But with a hefty £339 price tag and some tough competition, is this the future of wearable tech or yet another device we'll forget about in a few years? I spent some time with it to find out.

Google is looking to take on Apple and Samsung with its small, sleek and stylish Pixel Watch

DRESS TO IMPRESS

The watch looks great. It's one of the best-looking smartwatches out there, dare I say. It's sleek, stylish and – compared to other smartwatches – manages to actually look like a watch, rather than a computer strapped to your wrist.

The face features a curved screen that blends into a silver metal back. Two detachable strap connectors fit into each side and easily pop in and out if you want to try a different look.

Google has done a great job at making the watch comfortable to wear. It's light and the strap fits well without feeling tight. This is especially useful when exercising or sleeping, places where other wearables can quickly become uncomfortable.

While it isn't tiny, it's certainly smaller than your average smartwatch, which makes for a sleek design, but it isn't ideal when you're trying to use a display with already itsy-bitsy icons. Complicating matters further is the fact that a significant portion of the face isn't actually a usable screen, but a large bezel that wraps around it. Google does a great job at hiding this with a blacked-out backing on most apps and functions. But as you jab and poke at the screen trying to press buttons or type, its size quickly becomes frustrating.

YOU SNOOZE, YOU LOSE

The biggest disappointment of this watch is the battery life. Google claims it can last 24 hours but I was never able to achieve this. If you plan on only wearing the watch during the day and charging it each night, then you'll manage to get by.

The problem of battery life is most obvious when making use of the watch's sleep-tracking function. By the time I was going to bed each day, the charge would be down to between 20 and 40 per cent.

I was having to charge it for an hour or so before sleeping, and then again in the morning once I woke up. It's not the end of the world, but makes life difficult if you're a 'roll out of bed at the last minute' kind of person.

The watch does charge quickly, though. Google claims that you can get up to 50 per cent in 30 minutes, and I achieved similar charge times. Note, however, that Google supplies a charging cable for the watch, but says third-party chargers can't be used.

There is a battery-saving mode, but this turns off some of the watch's most useful functions, such as the ability to turn on

"EMAILS, MAPS, NOTES AND OTHER PRODUCTIVITY OPTIONS ARE ESPECIALLY WELL IMPLANTED IN THE WATCH"

the screen when you flick your wrist and the always-on display.

Battery life could be improved in the future through updates. Right now, the watch tracks your heart rate constantly, unlike most smartwatches that monitor it periodically. Why you'd need to know your heart rate at every second, I have no idea, but it can't be good for battery life.

FEATURES

This is hands-down one of the best examples of Android smartwatch software. While that sounds like a big claim, it's more a reflection on a history of somewhat poor attempts from different brands.

On the watch's home screen, you're presented with a customisable face. There is an overwhelming amount of choice here, ranging from simple clock faces, to the always dangerous custom-image option.

From the home screen you can also swipe to access 'tiles', which are your most-used functions. Quick buttons for the torch, Google Pay and other tools are also accessible here, along with notifications.

Google really wants you to know that it owns Fitbit with this watch, chucking the prefix 'Fitbit' at everything to keep that brand recognition alive. You can use 'Fitbit ECG', 'Fitbit today' and 'Fitbit exercise' to track a wide range of health stats.

Through the Google Play app store, you can download a huge list of other apps and most work really well with the watch. Emails, maps, notes and other productivity options are especially well implanted in the watch, using intuitive layouts and designs.

VERDICT

The Google Pixel Watch is almost the perfect Android smartwatch. This is a good sign that Google is heading in the right direction with wearables.

The watch looks and fits great, offers all the important features of a smartwatch and, while it comes together a bit awkwardly, the integration of Fitbit helps to offer a full range of fitness tracking.

The battery life and the small screen hold the watch back from its full potential, however. Hopefully, software updates or future iterations can take the Google Pixel Watch to a level where it can fight Samsung and Apple for that top spot.

RATING: ★★★★★

PROS:
- Stylish design
- Comfortable fit
- Fitbit integration

CONS:
- Poor battery life
- Small display
- Can't use third-party chargers

THE BEST ALTERNATIVE SMARTWATCHES

APPLE WATCH 8

Apple has been dominating the smartwatch market for a while. The Apple Watch 8 is the brand's best overall smartwatch, blending features and price for a comfortable package. It has a solid battery life, great GPS tracking, the ability to track everything from ovulation to ECG and blood oxygen, and the integration of a host of workouts. It's a less conventional design than most smartwatches, but looks great.

SAMSUNG GALAXY WATCH 5 PRO

Samsung is the biggest Android smartwatch brand, so perhaps Google's main rival. The Samsung Galaxy 5 Pro is made for fitness enthusiasts looking to track every bit of exercise. It has advanced GPS and a huge battery life to get you through multiple days. Its look is rugged rather than glamorous.

FITBIT VERSA 3

If you're looking for something a bit more affordable, Fitbit could be the way to go. It's Google-owned, but focuses on affordability and features over design. The Versa 3 includes built-in GPS, is both lightweight and comfortable and has plenty of fitness features. You'll need a Fitbit subscription to access the best features, but the watch still performs well without this.

Five of the best electric bikes

Battery and leg power combine to propel these five bikes. **James Witts** jumps in the saddle

Brompton Electric C Line Explore

£2,995, brompton.com

As Hoover is to vacuum cleaners, so Brompton is to folding bikes. It's *the* name. Brompton forged its reputation on a superb folding mechanism that collapses the bike down into a compact package. The C Line Explore makes great use of this to fold and unfold in fewer than 30 seconds.

With the 300Wh battery mounted on the front, the bike weighs 17.4kg. On the top of the battery is a small LED display to show its charge and which of the four power assistance modes you've selected. That assistance comes via the motor built into the front wheel. In theory, reaching over bars to change modes on the battery is hazardous; in practice, it's fine. Range is 30-70km (20-45 miles) depending on which mode you're in, the temperature and terrain. You still have to pedal, but you get six gears to help with that. The ride is great fun and there's also a Brompton app should you want to use your phone as a dashboard as you ride.

Riese & Müller UBN Five singlespeed

£4,719, r-m.de/en-gb

The UBN Five has just one gear, signalling its urban, commuting intentions and ensuring it'll be easier to maintain than a geared bike. The motor provides a smooth, natural-feeling assistance with a maximum power of 450 Watts. You can shift through its three assistance modes via a thumb lever, while the LED on the top tube tells you which one you're in.

The UBN Five weighs 18kg, has a battery that slots into the tube behind the front wheel, a 65-160km (40-100 mile) range and a svelte rack (panniers not included). The built-in headlight is plenty for urban riding and, rather neatly, the LED mode panel lifts up to reveal a USB-C port for charging your phone (although the mount to attach the phone to the bars is sold separately).

Volt Connect

£2,499, voltbikes.co.uk

The Volt Connect is a utilitarian bike with mudguards, a sturdy rack (complete with elastic straps), front and rear lights, and an integrated lock on the rear wheel. Its no-nonsense aluminium frame and reinforced wheels shout that this is a machine designed to batter the elements into submission.

The lithium-ion battery sits in the tube behind the front wheel and is removable for easy charging, although you need a key to do so. Activating the motor requires the key, too. That strengthens security, but isn't ideal if you tend to misplace things (keep the spares safe). As for the motor, it's a 250W unit that sits between the cranks. It delivers a smooth drive across its three modes and, used wisely, will power you for around 100km (60 miles).

Ribble Endurance SL e

£3,199, ribblecycles.co.uk

Ribble has gone to great lengths to make this bike light. Choose one of the smaller models and it could weigh as little as 10.5kg. It's so light you don't notice the battery that's integrated into the tube behind the front wheel. The 250W motor is nestled within the rear wheel and provides three levels of assistance, which you choose via a button just behind the handlebars.

How often you'll need assistance, however, depends on the terrain. The bike's lightweight nature means that on the flats, it's pretty easy to hit the motor's 25km/h limit. So the assistance is solely for helping you out on the hills, which means its range is over 100km (60 miles). The bike also comes with 22 gears, bulletproof wheels and a comfy saddle – albeit if you're wearing cycling shorts.

Saracen Ariel 50E

£4,499, saracen.co.uk

Saracen's Ariel 50E uses a 250W Shimano EP8 motor that sits between the cranks. It has three riding modes (Eco, Trail and Boost) and a Walk mode – a common feature on electric mountain bikes for when the gradients and mud make even pushing the bike a battle. Shimano's 504Wh-capacity battery provides the juice, though it's less than many of its contemporaries, so choose your mode carefully if you plan on riding all day.

There's 160mm of travel in the suspension fork at the front and 150mm at the shock absorber rear – enough for even the most serious of trails. It's a solid e-mountain bike, though perhaps one for the racier riders out there, as there's a relatively long reach to the bars.

Ideas we like...

Our pick of the month's smartest tech

↓

...start a radio show from anywhere

In a world where everyone thinks they should host a podcast, the Blast Mic is a dangerous but brilliant tool. A small device slapped with an aggressively neon display, the Blast Mic lets you record audio and upload it live to the Blast Radio app (for podcasts and audio shows). This cuts out all of the fiddly steps in the middle, allowing anyone to easily start a radio show without needing loads of equipment and time. It's the perfect gift for that family member who has a lot to say this Christmas, giving them a speaking platform that isn't the dinner table.

Blast Mic
$249 (£205 approx), blastradio.com

...a watch for every sport ever

Garmin's new Instinct Crossover Solar is for people who exercise all the time. It doesn't matter what sport you do, this watch's endless menus will have a mode for you. It tracks everything from your heart rate, to your sleep, and even how smoothly you ride mountain bike trails. And to help you fit even more exercise into your life, it can run using solar power, so it can stay on for an estimated 70 days without a charge.

Instinct Crossover Solar
£529.99, garmin.com

...the ultimate powerbank

Shargeek has tapped into the collective hearts of nerds with the Storm 2, by making the power bank interesting. Yes, it charges up your devices on the go, but it also lets you adjust the voltage and current, so you can choose how much power is sent to each device. You can track this through a display fitted into its stylish transparent top. But it's a big spend even for those who are obsessed with optimising their charging potential.

Shargeek Storm 2
$229 (£187 approx), shargeek.com

...smart lights on a budget

Making your home smart is expensive, especially when it comes to lighting. To combat this, Wyze has created a range of budget smart bulbs, with 16 million colour options. These clever bulbs can be programmed to adjust their colour in response to the light outside, to help you stay in sync with the sunlight. You can even programme warning lights if you leave your door open. Or you could just paint your interior in an array of neon colours...

Wyze Bulb Color BR30
$23.99 (£20 approx) for two, wyze.com

...dress to impress the metaverse

Although we're not quite sold on the metaverse yet, motion capture tech that can input your movements into it does sound like a lot of fun. Up until now, 'mo-cap' tech has been bulky, finicky, expensive, or all three. Sony's new Mocopi is looking to fix this. By dotting six sensors around your body, the Mocopi will be able to accurately replicate your movements online. It probably won't be perfect, but we're sure the eight active users on the metaverse won't mind.

Sony Mocopi
£TBC, sony.com

GETTY IMAGES

IDEAS WE DON'T LIKE...

...EXCLUSIVE AND PRICEY SPEAKERS

Porsche has now seemingly turned to interior design with its new speaker, adopting the unusual style of 'expensive car driving through your wall'. The 911 Soundbar will set you back a ridiculous £9,100, rewarding you with an exclusive car exhaust system strapped to a soundbar. It's not exactly a bad speaker – it has Dolby Atmos, 4K HDMI ports, and the kind of specs you'd see on leading competitors. It's just that you're just having to pay a hefty amount extra for the privilege of being one of the 150 owners to get one.

Porsche 911 Soundbar 2.0 Pro
£9,100, porsche-design.com

...HEATING YOUR HOME WITH BITCOIN

"Warmth never felt so rewarding" say the people behind Heatbit, a heater that earns you Bitcoin while it warms your home. It's a clever idea in theory, until you realise the minuscule amounts of Bitcoin you earn – the digital currency that lost roughly half of its value during 2022. Still, small earnings are better than nothing though, right? Maybe not when the heater itself costs a whopping $1,149! You can buy one of Dyson's air-purifying heaters and have a nice holiday for that sort of cash.

Heatbit
$1,149 (£935 approx), heatbit.com

SFP386

BBC Science Focus MAGAZINE SUBSCRIPTION ORDER FORM

Please complete the order form and send to:
FREEPOST OUR MEDIA *(please write in capitals)*

UK DIRECT DEBIT

☐ Yes, I would like to subscribe to/renew *BBC Science Focus* and receive 3 issues for £5. After this my subscription will continue at £22.99 every 6 issues

YOUR DETAILS (ESSENTIAL)**

Title _____ Forename _____
Surname _____
Address _____
_____
_____ Postcode _____
Home phone no _____
Mobile phone no** _____
Email** _____

☐ **I wish to purchase a gift subscription**

GIFT RECIPIENT'S DETAILS (ESSENTIAL)**

Title _____ Forename _____ Surname _____
Address _____
Postcode _____ Home phone no _____
Mobile phone no** _____
Email** _____

Instructions to your bank or building society to pay by Direct Debit DIRECT Debit

To: the Manager (bank/building society)

Address

Postcode

Name(s) of account holder(s)

Bank/building society account number

Branch sort code

Reference number (internal use only)

Originator's identification number

4 4 3 7 7 3

Please pay APS RE Our Media Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with APS RE Our Media Ltd and, if so, details will be passed electronically to my bank/ building society.

Signature

Date / /

Banks and building societies may not accept Direct Debit mandates from some types of account

KEEP IN TOUCH

BBC Science Focus Magazine* would love to email you with updates, special offers and promotions. You can unsubscribe at any time. **Please tick here if you would like to receive these (You can unsubscribe at any time.) ☐

We'd also love to tell you about other offers and promotions from our publisher, Our Media Limited. If you'd rather not be contacted this way please tick here ☐ Post ☐ Phone. Your data will be held by Immediate Media Company Limited (a parent company of Our Media Limited). For information about how we protect your personal data, please see our privacy policy, which can be viewed online at **immediate.co.uk/privacy-policy**

OTHER PAYMENT METHODS

☐ **UK cheque/credit/debit card** – £57.75 for 14 issues, **saving 25%**
☐ **Europe** inc Eire – £92.54 for 14 issues
☐ **Rest of world** – £102.90 for 14 issues
☐ I enclose a cheque made payable to Our Media Ltd for £ _____

Visa ☐ Mastercard ☐ Maestro ☐

☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐

Issue no ☐☐ Valid from ☐☐☐☐ Expiry date ☐☐☐☐

Signature _____ Date _____

If credit card address is different, please use the order hotline 03330 162 113

OVERSEAS Please complete the order form and send to: *BBC Science Focus Magazine*, PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF

***Offer ends 31 January 2023.** Offer only available to UK residents paying by Direct Debit. Your subscription will start with the next available issue. After your first 3 issues your subscription will continue at £22.99 every 6 issues, saving over 30% on the shop price. If you cancel within two weeks of receiving your second issue, you will pay no more than £5.

You may photocopy this form

EASY WAYS TO ORDER

ONLINE

buysubscriptions.com/SFP386

PHONE

03330 162 113†
(please quote SFP386)

POST

FREEPOST OUR MEDIA
(please write in capitals)

† UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages, call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am-5pm. *If calling from overseas, please call +44 1604 973 721.*

FSC www.fsc.org MIX Paper from responsible sources FSC® C020508

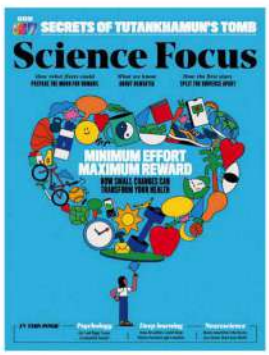
JANUARY SALE!

3 ISSUES FOR £5

WHEN YOU SUBSCRIBE TO *BBC SCIENCE FOCUS* TODAY*

- Trial **3 issues for £5** by Direct Debit!
- After your trial period, continue to **save 30% on the shop price**, paying just **£22.99 every 6 issues** by Direct Debit!*
- Receive every issue delivered direct to your door with **FREE UK delivery**
- **Stay up-to-date** with the fast-moving world of science and technology

YOUR FIRST 3 ISSUES FOR JUST £5!*



Science Focus
Understand HOW HORMONES WORK
The treasure BENEATH THE MELTING GLACIERS
Should you take A GENETIC HEALTH TEST?
HEALTH TARGETS DO THEY WORK?
Five-a-day, 10,000 steps, 2,000 calories...
How recommended daily allowances stand up to modern science
IN THIS ISSUE
Michael Mosley
Physics
Carnivore diet

JAMES WEBB SPACE TELESCOPE THE UNIVERSE SEEN ANEW
Science Focus
EVERYTHING YOU EVER WANTED TO KNOW ABOUT
THE MULTIVERSE

THE NEW WORLD OF ECCENTRIC EXERCISE

RUNNING UP STAIRS? LIFTING WEIGHTS? CLIMBING HILLS? IT TURNS OUT DOING JUST THE OPPOSITE MIGHT BE BETTER FOR YOU

WORDS: **DR MICHAEL MOSLEY**

BBC RADIO 4

Listen to the *Just One Thing* series with Dr Michael Mosley. Available on BBC Sounds. **bit.ly/just_one_thing_**

One of the best ways to get the most out of any workout is to make it 'eccentric'. You might think that running up a hill is better for you than jogging down it, or that climbing a flight of stairs is going to challenge your muscles more than walking down, but in fact, the opposite is true. It seems crazy, but this is the new science of 'eccentric exercise'.

The name comes from the fact that contracting your muscles (to climb stairs or lift weights) is called 'concentric exercise', but any work that goes into those muscles while they are stretched and elongated (as you go downstairs or lower the weights) is known as 'eccentric exercise' (pronounced 'ee-centric').

Tony Kay is professor of biomechanics at the University of Northampton. He explains that all forms of exercise create microscopic damage to the muscles. This stimulates the release of hormones which trigger your cells to rebuild that muscle stronger than before. Concentric exercises (such as bicep curls or squats) recruit and fatigue many different muscle fibres.

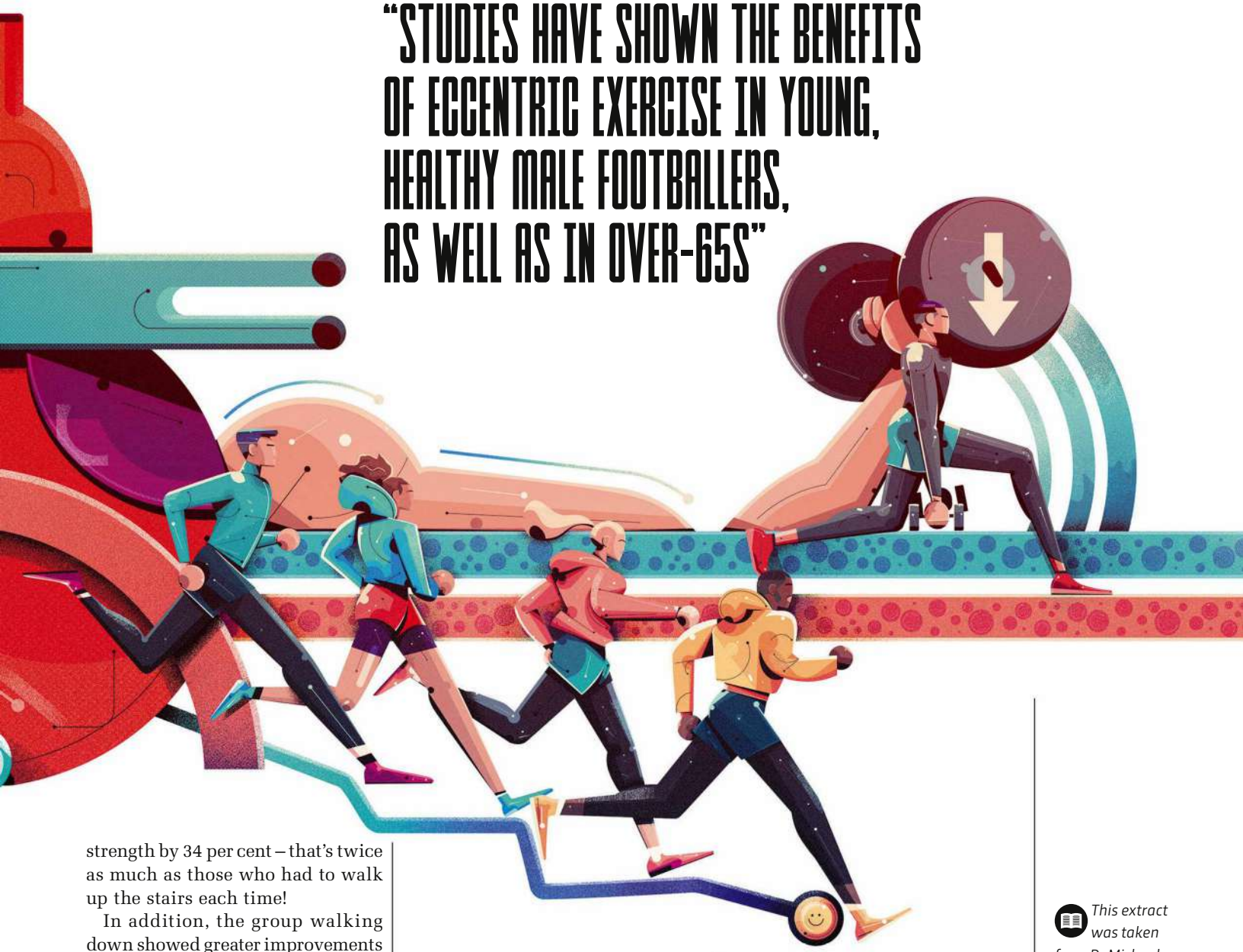
Although the eccentric part of the exercise (as we lower the weight, or sink down into a squat) recruits fewer fibres, it does so with a load that is up to four times higher. This, says Kay, creates far greater microscopic damage to those cells and fibres.

"The greater damage means the body burns more calories in the process of repair and recovery after the exercise has been performed," he says. "This raises the metabolic rate and increases strength in a far more effective way than conventional forms of exercise."

In one study, volunteers were randomly allocated to walking either up or down a set of stairs in a 10-storey building twice a week, and taking the lift in the other direction. Both groups saw health improvements, but the group who walked down rather than up the stairs ended up with greater improvements in resting heart rate (a reliable overall measure of fitness). They also saw a greater improvement in their insulin sensitivity and blood fat levels.

Plus, the group walking down saw greater improvement in muscle function and bone density than the group walking up. In fact, the group doing what I would consider to be the easier task improved their muscle

ILLUSTRATION: JOE WALDRON



"STUDIES HAVE SHOWN THE BENEFITS OF ECCENTRIC EXERCISE IN YOUNG, HEALTHY MALE FOOTBALLERS, AS WELL AS IN OVER-65S"

strength by 34 per cent – that's twice as much as those who had to walk up the stairs each time!

In addition, the group walking down showed greater improvements in a balance test, which would lead to a reduced risk of falls and injury.

Another study comparing older adults doing traditional versus eccentric exercise found the eccentric group had a 38 per cent improvement in leg strength, compared to just an 8 per cent improvement in the traditional exercise group.

Other studies have shown the benefits of eccentric exercise in young, healthy male footballers (who saw dramatic increases in strength), as well as in over-65s (who showed 30 to 50 per cent increases in strength and a 10 per cent increase in muscle mass in just six weeks). "The effects are far, far greater than we would expect from normal exercise," concludes Kay.

This is really impressive – and completely counterintuitive. And it turns out that any exercise that requires you to lengthen your muscles under resistance will have the same beneficial effect, whether it is running downhill or slowly lowering yourself down into a squat or a press-up. The way it works is that when you are going down, the muscles in your legs or arms lengthen to slow the pace of descent. Similarly, when you are lowering a set of weights, the muscles lengthen and have to work harder to protect your body from damage.

Kay points out that both yoga and pilates feature poses which require you to slowly lower yourself, thereby causing an eccentric contraction, which will, he says, "increase flexibility, muscle mass, bone density and strength".

Done right, not only will eccentric exercises keep you in good shape, they will also help your body to burn calories after you have finished – more so than a seemingly 'tougher' workout. This could be the metabolic secret that has been hiding in your workout all along! SF

This extract was taken from Dr Michael Mosley's new book, Just One Thing *(£16.99, Short Books), which is based on the BBC Radio 4 podcast of the same name.*

BBC SOUNDS
Listen to Jheni on *The Lost World Of Ice* on BBC Sounds
bit.ly/lost-ice

FROZEN IN TIME

by JHENI OSMAN

RAPIDLY MELTING GLACIERS ARE REVEALING ALL SORTS OF ANCIENT TREASURES. ARCHAEOLOGISTS ARE NOW RACING AGAINST THE CLOCK TO PROTECT THESE ANTIQUITIES BEFORE IT'S TOO LATE

On top of a nearby rock, a marmot perches, rotund from a summer of feasting. Cowbells chime in the green pasture below. The path ahead is blocked by a stubborn herd of sheep. As I approach, they scurry up the rocky cliff.

Balancing stone to stone, I cross a small stream, before zigzagging up the mountainside. The higher I go, the harder it is to breathe, the altitude and heavy backpack weighing me down. I'm now past the tree line. The ground is barren, except for some lichen clinging to the rocky ground.

A vulture circles above. Its vast wings outstretched, swooping in for a closer look, before soaring upwards on a thermal and disappearing from view into a cloud. Another looms out of the white-grey sky, then another. Soon five are overhead, eyeing up the carcass of a dead sheep lying beside the path.

Not far ahead is our destination – the Lötschepass in the Swiss Alps. Despite the pass being at an altitude of 2,690 metres, it was historically a trade route between the valleys far below.

"Colleagues once found the remains of a medieval cow skeleton at the top of the pass," says archaeologist Regula Gubler. "Radiocarbon dating revealed the cow was from the 15th or 16th Century. There are also written sources from that time showing people brought cattle across the pass to market." (Read more about radiocarbon dating on p80.)

The cow skull was discovered around a decade ago by a team of archaeologists surveying the remains of a permanent ice patch up on the pass. Since then, the site has yielded all sorts of treasures.

"Our best finds have been a whole assemblage of early Bronze Age things, from about 2000 BC," says Gubler. "There was a box made out of wood, two bows, fragments of arrow shafts and three flint arrowheads. Inside the box were cereal grains, which tells us what those people took along to cook. It seems like someone left half their equipment up here. The artefacts were really well made – those people knew how to use raw materials to create leather straps and bindings, for example."

"IT IS INCREDIBLY EXCITING FOR ME TO FIND SUCH ARTEFACTS, BUT IT'S ALSO VERY SAD. I'D RATHER THE ARTEFACTS REMAINED COVERED BY SNOW AND ICE"

Melting glaciers and ice patches around the world have created an opportunity for archaeologists to dramatically expand their understanding of how mountain life has changed through the millennia. One intriguing find revealed by melting ice was Ötzi 'the Iceman' who lived more than 5,000 years ago.

But archaeologists recognise such discoveries are bittersweet. Since Gubler has been involved in the project, the ice patch has dwindled. Now, in the summer months, it is just a small pool of water.

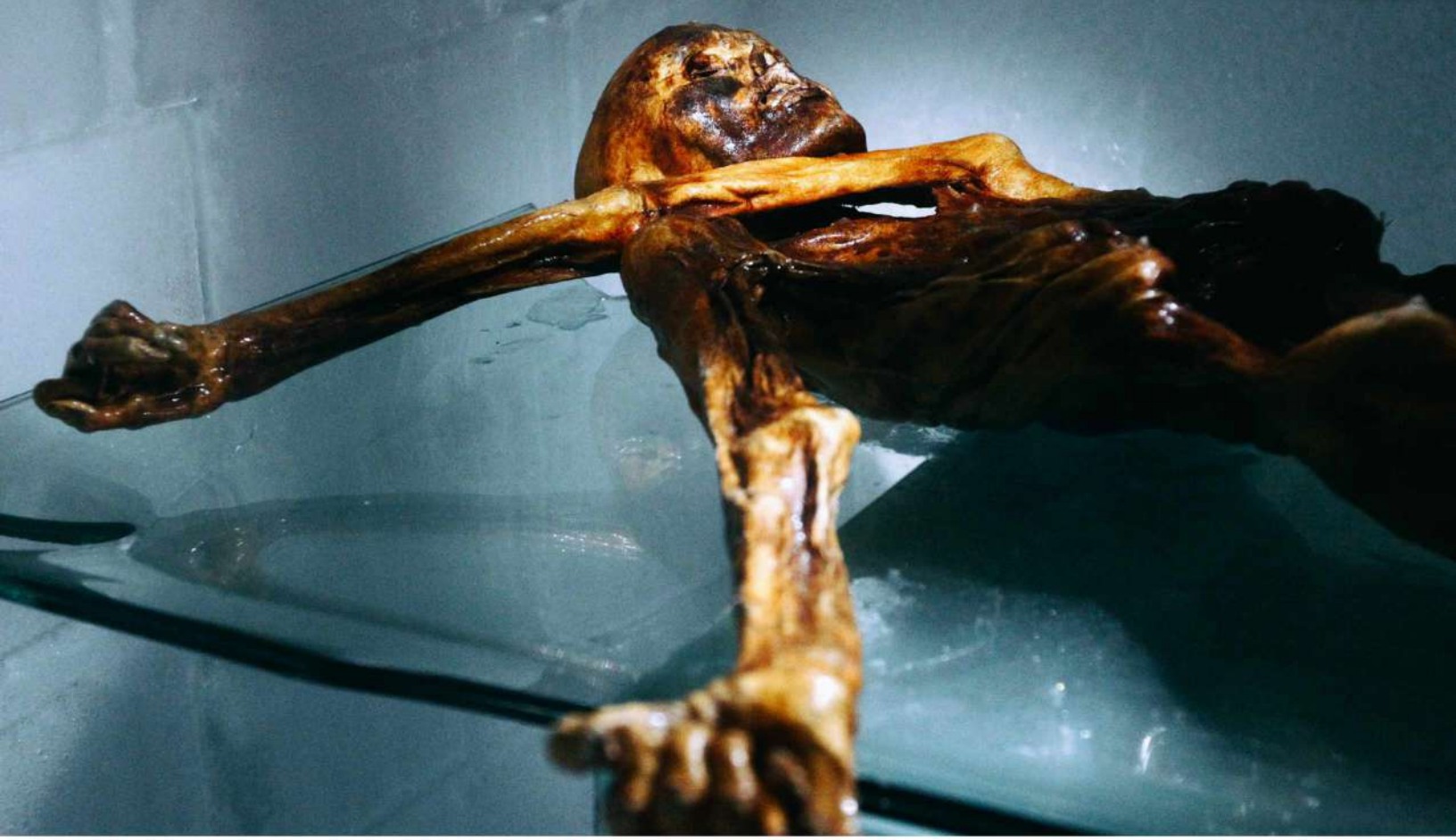
ABOVE LEFT Regula Gubler and a colleague catalogue artefacts

ABOVE Gubler found this bow in melting ice

ABOVE RIGHT Ötzi 'the Iceman' was discovered in a glacier on the Austria-Italy border in the 1990s

RIGHT A shoe found with the remains of a prehistoric man in the Bernese Alps

JHENI OSMAN, ARCHAEOLOGICAL SERVICE BERNE/ROLF WENGER, GETTY IMAGES X2



"As an archaeologist it is incredibly exciting for me to find such artefacts," says Gubler. "But it's also very sad. I'd rather the artefacts remained covered by snow and ice."

Glaciers move downhill, albeit extremely slowly. So whatever artefacts go into the glacier get spat out the other end. Ice patches, on the other hand, are stationary, so artefacts can be trapped in the ice for thousands of years. But as the artefacts emerge from the ice, the race is on to save the ancient treasures before they decay in the open air. Gubler is the only archaeologist working on such sites in this region of Switzerland.

All around the world, archaeologists are facing the same huge challenge of surveying and cataloguing sites in time, because thawing is occurring too fast for their limited resources.

THE RACE IS ON

Climate change is to blame for the rapid melting of glaciers, ice patches and permafrost. The rate of melting in the Alps is faster than in some parts of the world, because the level of warming at higher latitudes is greater than closer to the equator.

"In this year alone, we've lost about 6 per cent of the total glacier ice volume that is still present in Switzerland," says Matthias Huss, a glaciologist and head of Glamos, an organisation that monitors glaciers in Switzerland. "That is much more than ever before. In the last decade, we've typically seen 2 per cent ice volume lost per year. This year [2022] is three times more than the average of the last 10 years."

Glaciologists put 2022's dramatic ice loss down to a combination of three factors: minimal snowfall, heat waves and Saharan dust. With little snowfall during winter, there was a thinner protective layer than usual by the start of the summer, so the snow melted sooner, exposing the ice, and so ice loss started earlier in the season. Dust blown across the Mediterranean from the Sahara Desert between March and May made Alpine snow dirty, so it absorbed more solar radiation and melted faster.

ABOVE LEFT
Workers at a Swiss ski resort cover snow with a blanket, to prevent it from melting

ABOVE MIDDLE
The flooding in Pakistan in 2022's monsoon season was exacerbated by glacial melting

ABOVE RIGHT
This archway in the Lötschepasse was at the surface of the glacier just 10 years ago, but now juts far above it

The final nail in the coffin was the scorching heatwave in the Alps from May through to the beginning of September.

The rate of melting across the Alps is so severe that the Glamos researchers are starting to abandon some measuring stations. The station at Corvatsch has been shut down, as there remains little ice on the glacier left to measure. Glaciologists predict that 95 per cent of the 4,000 or so glaciers dotted throughout the Alps could disappear by the end of this century.

"2022 was worse than we expected," says Huss. "For some time, climate models have been predicting extreme weather would become more frequent, and our glacier models have shown that such extreme melt rates are possible. But we wouldn't have expected to see such extreme events yet. The future has already become reality."

SAVING GLACIERS AND LIVES

Globally, melting glaciers also threaten the lives of communities living nearby. Glaciers are like 'water towers' – they store snow that falls during the winter months then gradually release it through the summer, providing drinking water, irrigation for crops, and a cooling mechanism for power stations. Melting ice also impacts the local tourist industry. For example, the route to the summit of Mont Blanc is becoming more treacherous earlier in the season because of the increased risk of rock falls. In July 2022, a glacial ice shelf in Italy collapsed, killing 11 hikers. Severe glacial melt in the Himalayas exacerbated the deadly floods in Pakistan.

Extreme weather conditions need extreme measures. There has been talk of large-scale geoengineering projects to help save the glaciers.

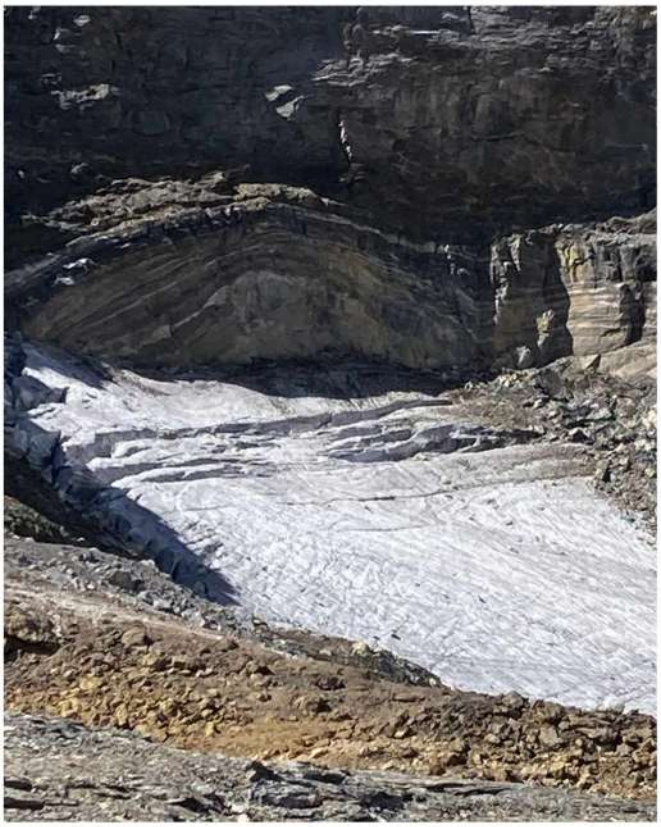
"Geoengineering projects work at a local scale, but they'll never work at the glacial scale," says Huss. "One could put some white blankets over the ice below a ski run to retain economic activities. But these technologies won't ever be able to save one entire glacier, and even less all the glaciers in the Alps or worldwide.

"We can save some of the glaciers in the Alps by reducing carbon emissions, it has been computed that about one-third of the ice volume that we have today in the Alps can be saved if the Paris Agreement is fully implemented. But this is pretty ambitious. Even then, we will lose most of the glaciers in the Alps – that is assuming we only see limited further temperature rise from today."

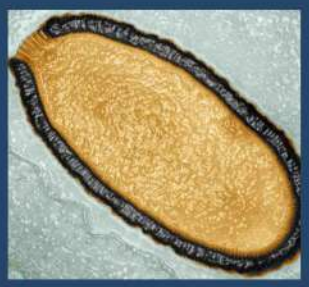
The goal of the Paris Agreement is to limit global warming to well below 2°C, ideally 1.5°C, compared to pre-industrial levels. Whether that can be achieved is a challenge

"WE WOULDN'T HAVE EXPECTED TO SEE SUCH EXTREME EVENTS YET. THE FUTURE HAS ALREADY BECOME REALITY"

GETTY IMAGES, SHUTTERSTOCK, JHENI OSMAN, JULIA BARTOLI/CHANTAL ABERGEL/IGS/CNRS/AMU



COULD MELTING PERMAFROST RELEASE THE NEXT PANDEMIC?



As its name suggests, permafrost is permanently frozen ground. It covers one-quarter of the northern hemisphere. Rising global temperatures are causing permafrost to melt, raising concerns that the 1.5 trillion tonnes of carbon trapped in frozen ground will be released into the atmosphere. But now a new concern is also rearing its head – the release of contagious bugs.

Recent research published in the *Proceedings Of The Royal Society B* in October 2022 revealed that the risk of viruses being transferred to new hosts was more likely in areas where there were large amounts of glacial meltwater.

In 2021, researchers at Ohio State University in the US discovered 15,000-year-old genetic material from 28 new viruses taken from ice samples from the Tibetan plateau in China. And back in 2014, under lab conditions, scientists at the National Centre for Scientific Research in France revived a virus taken from Siberian permafrost (pictured), making it infectious again after 30,000 years of being locked away in the frozen ground.

As the climate warms, melting permafrost does increase the risk of deadly bugs being released. It's a big leap to claim this melting could cause the next pandemic. But there are concerns that ancient viruses and bacteria could come into contact with new hosts that didn't exist years ago when they were initially locked away in the frozen ground.

for us all. Even if the Paris Agreement is implemented, temperatures are expected to rise for several decades before they stabilise in the second half of the century.

TICKING TIME BOMB

Back at the Lötschepass, I climb slightly higher to get a good view of a nearby glacier. Relatively small in size, its ice sheet snakes down the valley, covered by rocks and scree. The most striking feature is the head of the glacier. An arch is carved into the rock face. A decade ago, this arch marked the surface of the glacier. The surface now lies 10 metres below. It shows the glacier is not just shrinking in length, but also in depth – rapidly.

The still mountain air is broken by a shout. I head back down to the archaeological site.

"Birch bark! We've found birch bark!" yells Gubler triumphantly. "This was on my colleague's wishlist. She did her PhD on methods of conserving birch bark. I once found a whole bag made of birch bark, and she asked me to find her another!"

Buoyed on by the birch bark discovery, I scour the silt and rocks around the pond. I'm in luck. A vertebra – too large to be from a human. Gubler says that it's part of the medieval cow skeleton. I'm tasked with carefully bagging and cataloguing my find, so it can be taken down the mountain to the laboratory for analysis, along with the other discoveries.

Who knows what other treasures lie nearby, emerging from the melting mountain landscapes, waiting to be discovered. But as climate change kicks in, at the Lötschepass site, and all around the Alps, time is rapidly running out. SF

by JHENI OSMAN (@jheniosman)
Jheni is a freelance science journalist, author and BBC radio presenter.

RECOMMENDED HEALTH TARGETS: DO THEY WORK?

Get your five-a-day. Sleep eight hours. Drink eight glasses of water. These are just a few of the 'essential' health guidelines we're supposed to live by, but who can really manage all of the above? And do these 'commandments' stand up to scrutiny?

by **AMY FLEMING**

150 MINUTES OF EXERCISE A WEEK

You don't have to sweat it out in a smelly gym class to stay fit

The NHS recommends that UK adults get 150 minutes of moderate, or 75 minutes of vigorous exercise each week.

"These recommendations are the minimum that people need to do to gain health benefits from physical activity, based on four decades of research," says Gavin Sandercock, professor of sport, rehabilitation and exercise sciences at the University of Essex. "If you follow the recommendations, you're about 11-15 per cent less likely to die of anything, compared to people who do nothing, and your risk of dying of a heart attack is about 20 per cent lower."

But he says they're a watered-down version of the first activity guidelines from 1991, which were for 150 minutes of moderate – but preferably vigorous – activity, in addition to what you already do, in bouts of at least half an hour a pop.

"The science is really strong for vigorous activity," says Sandercock. "That doesn't mean with the eyes popping out, it just means having a higher heart rate. Everything we know about exercise physiology, everything I've learned in the past 25 years, tells me that vigorous is best and I recommend it to anyone who is healthy enough to do it. If you want to get fitter, you have to work harder."

In surveys on physical activity, people tend to exaggerate how much they've done, says Sandercock. It's easier to determine accurately how much vigorous activity you did, and not kid yourself about it. "If I asked you how far you'd run, you probably know, whereas if I asked you how far you walked this week, you'd have trouble answering because it's more of an incidental activity," he says.

Dr Koula Asimakopoulou, a reader in health psychology at King's College London, worries that these targets don't provide any sense of motivation. "Different people will have different ideas of what 'moderate' and 'vigorous' mean," she says.

But even if you're motivated to read the small print for examples (which for 'moderate' exercise include walking, lawn-mowing and rollerblading, versus running, swimming or aerobics for 'vigorous' activity), that alone is unlikely to be enough to start new behaviour so you can get fitter. Planning, removing any friction by getting your running kit or wet-weather gear ready the night before, finding an activity you enjoy and doing it with friends will all help make those fitness dreams become real.

ILLUSTRATION: JOE WALDRON

FIVE PORTIONS OF FRUIT OR VEG A DAY

No, chips, mash and crisps don't count as three

Five-a-day started out as a health marketing slogan in the US.

"[It was] loosely linked to populations that had more fruit and vegetables having lower risk of heart disease or longer lives," says Dr Duane Mellor, a British Dietetic Association spokesperson and registered dietitian. "The World Health Organization data now shows eating half a kilo of fruit and vegetables daily is a minimum to see lower instances of disease."

Five good handfuls should provide this quota, but the more the merrier.

Five-a-day may be super catchy, but in practice it can be problematic. Fruit juice counts as a daily portion in the UK, even though you're getting the concentrated sugar hit of many more fruits than you'd eat, without the fibre, potentially causing a sugar rush and tooth decay. In the UK, we don't count starchy, carb-rich potatoes (or yams), but in Australia spuds are allowed – after all they are a key source of vitamin C.

"A simpler message is try to eat as many different fresh or frozen – or if that's not possible, tinned – fruit and vegetables as possible, in two meals a day," says Mellor.

Mellor says giving the vegetables a starring role in meals is key to long-term health benefits. "We may be tempted to eat more fruits because they taste nicer," he says. "Likewise, condensing the fruit and veg down to a smoothie, you're losing the foundation, the building blocks of meals. If you take the vegetables out of the meal, the risk is your meal is going to comprise things with less vitamins, minerals and fibre and more calories. You need to make vegetables the bulk of a meal, and then try to make them interesting."

Variety is important, agrees Dr Sarah Berry, associate professor of nutritional sciences at King's College London, and chief scientist at personalised health research company, ZOE. According to Berry, recent research by ZOE's partner organisation, the American Gut Project, has highlighted the importance of eating a variety of fibre from around 30 different plant species as being key to better health.

While some argue that we should be surpassing five portions of fruit and veg a day, Berry is cautious. "The majority of people in the UK – 70 per cent of adults and over 80 per cent of children – do not reach the five-a-day target, so changing it to something more ambitious may not be helpful," she says.

Asimakopoulou warns that short catchphrases are not enough to spark behaviour change. Instead, we need to consider SMART objectives. SMART stands for specific, measurable, achievable, realistic and time-based targets.

"Having a goal is not equivalent to performing it," she says. "Psychologists have discovered that if you have an intention to get five-a-day, you'll be most likely to translate it into behaviour if you plan when, where and how you will achieve this goal, along with forming a Plan B for what you will do if the when/where/how plan is broken by life events."

"NOBODY CAN REALLY SAY HOW MUCH EVERYONE NEEDS TO DRINK, AS WE ALL HAVE DIFFERENT BODIES, DIETS AND ACTIVITY LEVELS"

EIGHT GLASSES OF WATER A DAY

If in doubt, check your pee

In the UK, the NHS recommends six to eight glasses, or up to 1.2 litres of fluids, a day, pointing out that we also get water from food. Harvard Medical School recommends four to six cups a day. But it's the more extreme two litres of water a day advice that has won the internet.

In 2016, the idea that getting most of your liquids from water is more beneficial was debunked by Dr Stuart Galloway, an associate professor in physiology, exercise and nutrition at the University of Stirling. His study showed a range of drinks, including diuretics like lager and instant coffee, didn't stimulate any additional fluid loss than water when drunk in normal quantities.

But nobody can really say how much everyone needs to drink, as we all have different bodies, diets and activity levels, not to mention varying environments (hot, dry, humid, etc). Most people can tell if they need more water because they feel thirsty, although this urge diminishes in old age. If in doubt, for the majority of adults, the number of trips to the loo can be a potentially useful guide to adequate hydration, says Galloway.

"It accounts for differences in fluid losses due to environment, or activity level, as well as variations in fluid intake. A rough rule of thumb would be four to six visits to the toilet to pee during a typical day, if adequately meeting your water requirements." More than six pees means you're overdoing it, while less than four means you probably need to drink more.

"This approach can have some shortcomings, such as impacts of any alteration in kidney function with age, certain medications, or different beverage compositions that all affect urine concentration and volume," he warns. "So it is a rough rule of thumb rather than an accurate guide."

Urine colour is also useful, with similar caveats, he says. "To get the best idea, don't rely on a single marker but evaluate using a combination."

GETTY IMAGES X2

SHOULD WE DITCH RDAs?

RDA – a term from the US that's also familiar in the UK – stands for Recommended Dietary Allowance. In the UK and Europe, the official ideal daily measure for nutrients is called the 'dietary reference intake'. They're not identical, but both indicate the optimum levels of nutrients needed every day to keep most of the population healthy.

Based on averages, these figures can be misleading for individuals, says Dr Susan Fairweather-Tait, professor in health policy and practice at the University of East Anglia Medical School, with a special interest in micronutrients. "Not everybody needs that level of intake," she says.

Nevertheless, she adds, seeing these figures on product and supplement labels is useful as a rough guide. But rather than being taken as instruction for what you need to ingest each day – which would be impossible to calculate precisely, as foods vary so much and you're unlikely to weigh each portion – they are most important in avoiding overdosing.

"[With supplements] people often think, 'one capsule good, two must be better'. But you can buy supplements in massively high doses, and it's dangerous. Taking too much vitamin C won't do you any harm, but things like vitamin D and vitamin A can be quite dangerous. With selenium, the gap between what you require and what becomes toxic is very narrow, so if people read an article saying selenium is a great antioxidant, they could go over the top and make themselves ill. Consumers are being misled, they're wasting money and putting their health at risk."

Dr Sarah Berry, associate professor of nutritional sciences at King's College London, agrees. "While RDAs are useful on a population level, not everybody will need to supplement to reach their ideal amount of a certain nutrient," she says. "As humans we eat food, not individual nutrients, so for most people eating a variety of foods is likely to provide the necessary key nutrients needed for health."

Exceptions include pregnant women, vegans and people with specific health conditions taking their doctor's advice. If in doubt, Berry does not believe there is any harm in taking a standard dose multivitamin as an 'insurance' policy.

14 UNITS OF ALCOHOL A WEEK

Moderate consumption can still cause harm

According to UK guidelines, adults should stick to no more than 14 units of alcohol a week, spread over a period of three days or more.

"If you stick to a maximum of 14 units a week, your chances of dying of an alcohol-related disease are probably one in 100 or less," says Sir Ian Gilmore, chair of Alcohol Health Alliance UK and founder of Liverpool Centre for Alcohol Research. "It's estimated most people would accept a risk of one in 100, as nothing in life is free of risk."

The struggle, however, is getting people to adopt those recommendations. The drivers of how much people drink, and how much harm is seen, are basically price, availability and marketing, he explains.

Plus, as he says, most people enjoy a drink. "It's associated with fun and celebrations. I've never

GETTY IMAGES X2

"THE VAST MAJORITY OF PEOPLE DO NOT KNOW THAT ALCOHOL IS LINKED TO SEVEN COMMON CANCERS, INCLUDING BREAST CANCER AND COLON CANCER"

heard someone say 'so-and-so is a really good smoker, he can really hold his fags'. There's still that heroic image around drinking."

People are also very bad at remembering advice on units, says Gilmore. "I can't help sometimes thinking people are quite keen to be confused and say, 'Oh, well, it's all too difficult. It's not my problem anyway.'"

But he says the majority of harm is not just seen in heavy, dependent drinkers. "It's actually in the people in the middle who are not alcohol-dependent. And if you could just shift the whole of the consumption curve down by a couple of units, you would save thousands of lives."

According to Asimakopoulou, lowering your alcohol consumption is all about intention. "You need to think about opportunity and motivation – so you would need to make the conscious decision to not have a drink if, for example, you are out every evening."

Reading up on the cold, hard facts is the first step towards that motivation, she says. If you don't know and believe in the benefits of cutting down, it's never going to happen. Planning when you will and will not drink is useful, as is knowing the units in actual drinks that you enjoy.

"The vast majority of people do not know that alcohol is linked to seven common cancers, including breast cancer and colon cancer," says Gilmore. Alcohol-free months can help, he says, as long as they're not seen as a free pass to get blotto the rest of the year (they're not).

"Alcohol Change, the charity behind Dry January, has shown that six months and 12 months afterwards there is a significant improvement in some people's relationship with alcohol. It's about showing people that they can go without, allowing them to reset their relationship with alcohol," says Gilmore.

2,000 CALORIES A DAY

All calories are not made equal

Calories give us an idea of how much energy foods and drinks contain, and have been a dietary obsession in recent decades. Most of us can recite that women need 2,000 calories a day, and men need 2,500. But as NHS guidelines point out, "an ideal daily intake of calories varies depending on age, metabolism and levels of activity, among other things."

Calories are nice theoretical units, says Mellor, but are flawed. While a hazelnut contains a certain amount of energy potential, when eaten it requires quite a lot of energy to break it down – and still more energy will escape digestion. "This is because the energy is inside the fibre, which we can't break down. Whereas the same number of calories from instant noodles are a lot easier to get hold of," he says.

Mellor points to the work of Kevin Hall at the US Department of Health and Human Services, who has found that eating ultra-processed foods compared to unprocessed foods led to greater energy intake and weight gain, despite the foods having the same calories, sugar, fat, sodium, fibre and macronutrients.

Then we need to account for variation in unprocessed foods. "If you've got a number on a label, because of biology, it can vary by about 20 per cent," says Mellor.

Even apples from the same tree can differ in sugar content by 10 per cent, according to which got the most sunshine.

"If you're going to look at calories, go for foods with more fibre, protein, vitamins or minerals in them which give you bulk and more satisfaction," he advises. But rather than sweat the numbers, he says to focus on more variety in terms of colour, fibre and nutrients.

Berry doesn't believe that calories are a useful measure for health. "We know that there is much more to food and health than calories. Moving the conversation away from calories and how much you weigh, and towards how you feel and improving our relationship with food and eating healthier foods, is much more helpful. Focus on how healthy a food is, not on how many calories it has."

"A LOT OF PEOPLE ARE OUT OF TOUCH WITH THEIR HUNGER AND FULLNESS CUES, THEIR ENERGY LEVELS AND THEIR ENJOYMENT OF FOOD"

As ZOE's studies have found, different foods cause harmful blood sugar or fat spikes in different people. "Understanding what works for you is simple but crucial," says Berry. "A lot of people are out of touch with their hunger and fullness cues, their energy levels and their enjoyment of food. Our members want to feel better, not worry over a number on the scales. Nutritious foods lead to enjoyable meals."

GETTY IMAGES X2, ALAMY

10,000 STEPS A DAY

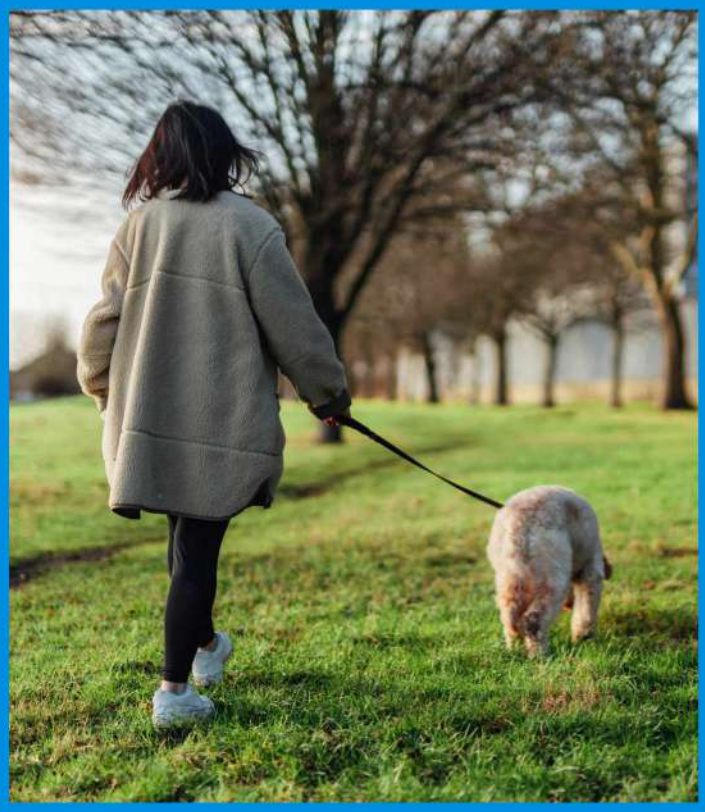
Count your steps, but tread carefully…

"The 10,000 steps target was a gimmick that was produced for the 1964 Tokyo Olympics, by a pedometer company," says Sandercock.

But one of the big controversies is whether we should count incidental movement in the activity guidelines. "If we did 10,000 [proper] steps a day everyone would be doing around 1,680 minutes per week of activity, but it's just moving around. If you're wearing an accelerometer or pedometer, it could misconstrue any movement as a step."

If you're trying to increase your walking, a pedometer can help, but might it not work for long. One 2013 study found that over a period of four weeks, a pedometer increased participants' walking more than being given walking goals in minutes, although after this time, walking times started to decrease again. Perhaps the novelty had worn off. If you want to sustain these gains, you might be better off getting a dog.

Sandercock's advice, depending on how old you are, is to up your steps by 15 per cent. "That's been shown to be effective in studies, and there's also really good evidence to show that older adults don't need to do 10,000 steps. Usually, 6,000 steps is enough to keep them out of things like frailty classifications, and this is associated with better health."



EIGHT HOURS OF SLEEP A NIGHT

Get enough shuteye and reap the health benefits

Seven to eight hours of sleep a night has been proven to be the magic number of hours for adults, with babies, children and teenagers needing more.

"This amount of sleep will ensure the brain has the appropriate time to do what it needs for healthy functioning. Some people can tolerate a shorter window of time, and others need a bit more, but seven to eight hours is the average," says Dr Nilong Vyas, managing director at paediatric sleep consultancy Sleepless in NOLA and a medical review expert at the Sleep Foundation.

The majority of people who get seven or eight hours per night report feeling better rested, with improved mood and health, she says. But it's an ideal target rather than something to get stressed about. So if focusing on seven to eight hours of shuteye is not helping you sleep better, another target to strive for is eliminating electronics at least one hour before bedtime. "This is an extraordinarily hard task and target to achieve for many. However, prioritising both targets will ensure an avalanche of health benefits," says Vyas.

In terms of behaviour change, "it is more about placing the sleep goal within a lifestyle that allows you to do it, by telling yourself that the sleep goal is higher value to you than the staying-up-late-to-get-the-overdue-report-written goal," says Asimakopoulou.

Planning when, where and how you will achieve the goal is vital, she says, along with consciously deciding to drop competing goals that prevent you from getting enough sleep. SF

by AMY FLEMING (@amy_fleming)
Amy is a freelance science and health writer.

Science Focus

ourinsiders

CALLING BBC SCIENCE FOCUS READERS

SHARE YOUR THOUGHTS AND EARN EXCITING REWARDS!

As a valued reader of *BBC Science Focus* we'd love you to be part of **Our Insiders** – an exclusive online community that rewards you for sharing your feedback about the magazine, as well as other topics. You'll be entered into our monthly prize draw for each survey you complete, as well as gain access to other special offers and rewards!

TO GET STARTED, VISIT

ourinsiders.com

Q&A

YOUR QUESTIONS ANSWERED

... WHY DO I FEEL BETTER AFTER I'VE CRACKED MY NECK?
... WHY DOES MY MOUTH OPEN WHEN I APPLY MASCARA?
... DO WE REALLY NEED TO ACCEPT COOKIES ON A WEBSITE?
... MY WORK CREATIVITY HAS HIT ROCK BOTTOM. ARE THERE ANY TRICKS TO GET THE CREATIVE JUICES FLOWING?
... WHICH DINOSAUR WOULD HAVE THE BEST CHANCE OF SURVIVING IN TODAY'S MODERN WORLD?
... WHY ARE FISH FISH-SHAPED?
... ARE THERE ANY BENEFITS TO USING A DAYLIGHT SAD LAMP?
... HOW DOES RADIOCARBON DATING WORK?
... WHAT IS BIPHASIC SLEEP?

Email your questions to
questions@sciencefocus.com
or submit on Twitter at
@sciencefocus

OUR EXPERTS

DR HELEN SCALES
Marine biologist

PETE LAWRENCE
Astronomy expert

DR CHRISTIAN JARRETT
Psychologist and author

DR STEVE BRUSATTE
Veteran palaeontologist

PROF ALICE GREGORY
Sleep expert

HAYLEY BENNETT
Science writer

DR HELEN PILCHER
Biologist and science writer

DR NISH MANEK
Medical expert and GP trainee

LUIS VILLAZON
Science and technology writer

PROF PETER BENTLEY
Computer scientist

DR CLAIRE ASHER
Science writer

ILLUSTRATION: DANIEL BRIGHT

PATRICK RYAN, BELFAST

CAN ANIMALS BE ALLERGIC TO HUMANS?

You probably know someone with a cat or dog allergy, but can pets also be allergic to us? Allergies are caused by an overreaction of the immune system to a substance, such as pollen, peanuts, or pet saliva. Just like humans, animals can have allergies to a variety of substances, and although it's rare, some pets are allergic to our dead skin cells, known as dander. Different pets can even be allergic to each other's dander! Common allergy symptoms include breathing difficulties or skin irritation. If you think your pet may have an allergy, seek advice from your vet. ***CA***

NATURE'S WEIRDEST CREATURES...

FRIED EGG JELLYFISH

How do you like your eggs? If the answer is, 'fried, salty, and weirdly pulsing with life' then read on. With its yellow dome sitting on top of a smooth translucent bell, the fried egg jellyfish, *Cotylorhiza tuberculata*, bears an uncanny resemblance to the popular breakfast item. Beneath this egg-like bell is a frilly, ruffled 'underskirt' of trailing appendages. Some are tipped with purple blobs that house zooxanthellae, the same symbiotic algae that give certain corals their characteristic hue. The symbiotic organisms receive a place to live, and in return, generate energy for their hosts via photosynthesis.

The fried egg jellyfish feeds on tiny aquatic organisms, such as zooplankton and phytoplankton, which it ingests via specialised tentacles called oral arms. It is common in the Mediterranean, Aegean, and Adriatic Seas, where the adult form can grow up to 35cm across. Vast blooms of it can appear during summer and autumn months, which can be an annoyance for swimmers. We should be more tolerant. The jellyfish's sting has little or no effect on humans, and the blobby invertebrate could even prove to be our ally. An extract derived from the fried egg jellyfish has been shown to possess anticancer activity. So maybe one day, we will learn to love them; not just for their looks, but for their pharmaceutical value too. ***HP***

KEVIN HARDING, BEDFORD

WHY DO I FEEL BETTER AFTER I'VE CRACKED MY NECK?

It is thought that one of the most common causes of neck 'cracking' is gas bubbles in the synovial fluid escaping a tight space. This synovial fluid is a lubricant between the joints, formed by a combination of carbon dioxide, nitrogen and oxygen.

If you deliberately roll your neck, it is thought that you can sometimes release these bubbles, resulting in a series of popping sounds that may sound like cracking. The release of the gas build-up explains why muscles or joints often feel looser and more comfortable after they've been 'popped' or 'cracked'. ***NM***

AMY MILLS, VIA EMAIL

WHY DOES MY MOUTH OPEN WHEN I'M APPLYING MASCARA?

'Mascara face', as it's sometimes called, is thought to be a result of nerves in our brains cross-firing. The two nerves controlling our eyeball and eyelid movements are rooted in a very similar part of the brain to another nerve that controls the opening and closing of our jaw. So, it's possible that when the two nerves in charge of eye movements are activated, they trigger off the nearby mouth-opening nerve. This is only a theory, though. A simpler explanation is that we've learnt that opening our mouths stretches our skin, which helps with applying make-up, so we keep doing it. ***HB***

STEVEN CHURCH, VIA EMAIL

DO WE REALLY NEED TO ACCEPT COOKIES ON A WEBSITE?

Website cookies are little files of information that a webpage tells your computer to store, and then access later. They're named after fortune cookies, an object with an embedded message. They tend to be the same size: 4,096 bytes. Not so big, but when each website could be saving 50 or more of them, they can be used to store a lot about you.

There are three types of web cookies: session cookies, persistent cookies, and third-party cookies. When you click into 'manage cookie preferences', the first two types may be listed under 'necessary' or 'preferences', while third-party cookies may be listed under 'tailored advertising', 'marketing' or 'analytics'.

Session cookies only last while you have that webpage open. They are often helpful – they enable an online shop to remember you placed items in the cart so that when you check out you still see them there. If you were to block these cookies, then many websites – including social media, online shopping and banking – would not work.

Persistent cookies, also known as first-party, permanent or stored cookies, don't go away so easily. These cookies remember your preferences, such as login information, language selections and bookmarks. They make your browsing experience more efficient and easier. It is possible to block first-party cookies, but some websites may not function properly if you do this – you might not be able to log in and online shopping may malfunction.

Third-party cookies, also known as trackers, are more insidious. They are used to track your online behaviour: what you click on, what you buy, what you like and dislike. The data from these cookies are secretly sold by the websites to marketing companies, who then use it to profile you for personalised advertising or marketing campaigns. You can deselect all such cookies, or even block all third-party cookies in your browser (browsers such as Safari, Firefox and Chrome disable trackers already). If you disable these cookies, you will no longer see personalised adverts and your data will be a little bit safer, and webpages will work just fine. ***PB***

Are you happy to accept cookies?
To manage your cookie choices now, including how to opt out where our partners rely on legitimate interests to use your information, click on Manage my cookies.
Yes, I'm happy
Manage my cookies

NATUREPL.COM, GETTY IMAGES, ALAMY X2. ILLUSTRATIONS: DANIEL BRIGHT

DEAR DOCTOR...

MENTAL HEALTH QUESTIONS DEALT WITH BY OUR EXPERTS

RACHEL HARDMAN, SOUTHEND-ON-SEA

MY WORK CREATIVITY HAS HIT ROCK BOTTOM. ARE THERE ANY TRICKS TO GET THE CREATIVE JUICES FLOWING?

Humans are inherently lazy – we can't help it, it's just that we evolved to conserve our energy. But one consequence is that we tend to revert to tried-and-tested thinking patterns. They're low effort and usually reliable, but unfortunately, they also tend to be boring and predictable.

One way to jolt your brain out of such ruts is to mix up your routine. So, let's say you're used to brainstorming ideas on your keyboard at your desk in the afternoon. Instead, get out of the office early in the morning, go up to the top floor, or into the garden, or up a hill or by a river – somewhere that feels completely different – and take a voice memo or pencil and paper, and let your ideas flow.

Other tips to try include: reminding yourself of the creative challenge just before you go to bed at night and then coming back to it the next day (this will allow the problem to incubate and your unconscious processes to get to work); going for a brisk walk; brainstorming with someone who has a completely different background and perspective than you do; or try exploiting the creative power of relaxation – light some candles, run a bubble bath, close your eyes and see what your brain comes up with (just don't fall asleep). *CJ*

MEL CARTER, VIA EMAIL

WHICH DINOSAUR WOULD HAVE THE BEST CHANCE OF SURVIVING (OR EVEN THRIVING) IN TODAY'S MODERN WORLD?

Dinosaurs do live today: as birds. Birds evolved from dinosaurs, and are part of the dinosaur family tree, so technically some dinosaurs did survive the asteroid impact 66 million years ago, by virtue of their fast growth, their biology that allows them to eat seeds, and their ability to fly away from danger. And there are some 14,000 species of them flourishing today. But what about the dinosaurs that perished? Many of them probably could survive today.

Dinosaurs ruled the world for 150 million years, and endured hot and cold spells, volcanic eruptions, and changing sea levels. There is nothing about today's world that would be fatal to them. With that said, the major difference between the world of dinosaurs and today is that our modern Earth is considerably colder, with ice caps at the poles. In cooler climates, big animals are often favoured, because they can retain heat more easily, as are smaller animals that have insulation like hair or feathers to stay warm. That suggests that huge dinosaurs like the long-necked sauropods and small, feathered-covered dinosaurs like *Velociraptor* and kin would be especially resilient in today's world. Smaller dinosaurs without feathers would probably be the most vulnerable. ***SB***

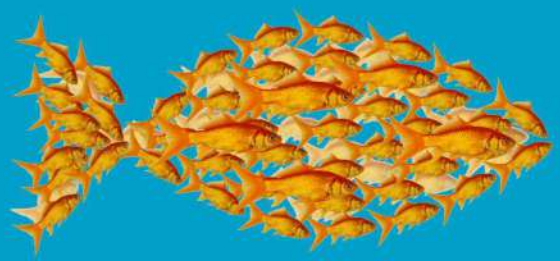
CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

WHY ARE FISH FISH-SHAPED?

The classic fish-shaped body — a squashed teardrop with a pointed nose and tapered tail — has evolved time and again. There are tuna shaped like this, sharks, marlin, mackerel and thousands of other species that spend a lot of time swimming. The reason it's so common comes down to the fact that water is around 800 times denser than air, and much stickier, which means it takes far more energy to move through it. You can feel the difference, when swishing your hand through water compared to air. Being fish shaped, or 'fusiform', allows a body to cut through the water while creating minimal drag. This is the best energy-saving shape for swimming animals, including not just fish, but also dolphins, whales, and extinct ichthyosaurs.

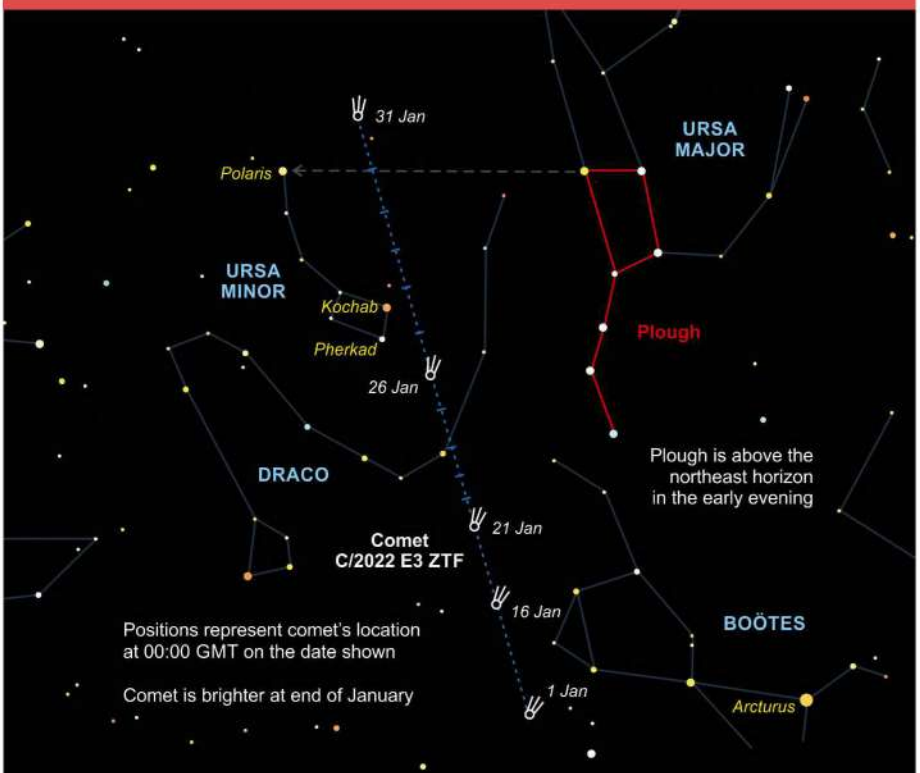
Other components of the classic fish shape are the fins, in particular the tail or 'caudal fin', which swishes from side to side to create propulsion. Fish with different swimming habits have differently shaped caudal fins. Tuna and other fast swimmers tend to have a forked or crescent-shaped tail which is good for long-distance, endurance swimming. Fish such as groupers and barracudas have much wider caudal fins, which are harder work to push through the water but excellent for putting on quick bursts of speed when they ambush prey over short distances.



Of course, there are many ways of being a fish and not all are superb swimmers. Many other body shapes have evolved among slow and sedentary fish, from S-shaped seahorses to four-legged frogfish and square boxfish. *HS*

GETTY IMAGES X2, ALAMY ILLUSTRATION: PETE LAWRENCE

ASTRONOMY FOR BEGINNERS



HOW TO SPOT A COMET

WHEN: THROUGHOUT JANUARY

If you find the precision of astronomical predictions impressive, this month's topic might change your mind. C/2022 E3 ZTF is a well-placed comet, possibly about to break the naked eye visibility threshold. However, comets are notoriously difficult to predict, sometimes likened to cats in the way they ignore predictions and do just whatever they please. In astronomy, a bright comet roughly describes any such object visible through binoculars or a small telescope. Many fall well short of this requirement!

Comet C/2022 E3 ZTF is a long period comet discovered on 2 March 2022, with an orbit estimated as longer than 50,000 years. Consequently, this is a non-periodic comet; that's what the 'C/' in the name means. A periodic comet is typically regarded as one with an orbital period of less than 200 years. The '2022 E3' part of the name indicates 2022 as the year of discovery, it being the 3rd (3) comet discovered in the fifth half-month of that year (E). Comet discovery half-months are indicated by the letters A, B, C and so on, with I being omitted to avoid confusion with 1. The 'ZTF' in this comet's name indicates that it was discovered by the Zwicky Transient Facility at Mount Palomar in California.

As it tracks near to the North Star, Polaris, comet C/2022 E3 ZTF passes close to the two middle brightness stars in Ursa Minor, called Kochab and Pherkad. Being relatively close to Polaris, the pair are often described as 'the Guardians of the Pole'. To navigate this area of sky, the best starting point is the Plough or Saucepan pattern. Use our chart and see whether you can get a view of this comet, but be prepared because it may not be as bright as you might imagine. Then again, if something unexpected happens, it may well be brighter! ***PL***

LISA SEYMOUR, DURHAM

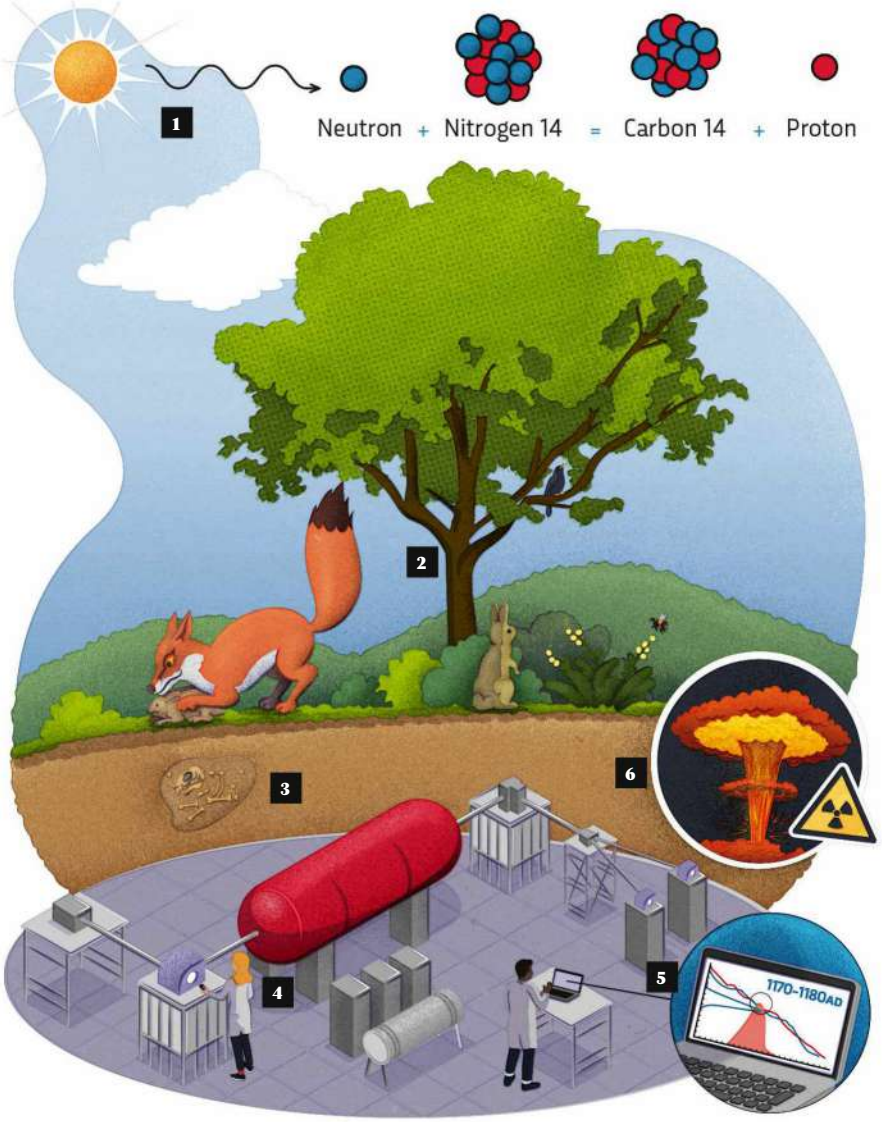
ARE THERE ANY BENEFITS TO USING A DAYLIGHT SAD LAMP?

Seasonal affective disorder (SAD) is a type of depression that comes and goes in a seasonal pattern. The exact cause isn't fully understood, but it's often linked to reduced exposure to sunlight during shorter days.

Some people find that a light box, called an SAD lamp, can help. These produce a very bright light to simulate sunlight. This is thought to encourage your brain to reduce melatonin (the hormone that makes us sleepy).

Light therapy has been associated with a reduction in fatigue on a short-term basis. However in 2019, Cochrane (the global independent research network whose reviews are considered the gold standard for research) published a systematic review of light therapy for SAD, and concluded that the quality of evidence about whether light therapy prevents winter depression is very low. However, some studies have found it's effective for treatment during a SAD phase, especially first thing in the morning. It's worth bearing in mind that it can take a few weeks to work, and is often not available on the NHS.

Most people can use light therapy safely. The recommended light boxes have filters that remove harmful ultraviolet (UV) rays, so there's no risk of skin or eye damage for most people, but make sure that you choose a light box that is medically approved for the treatment of SAD, and produced by a fully certified manufacturer. It's rare for people using light therapy to have side effects, but some do report agitation or irritability, headaches, eye strain, sleeping problems (avoiding light therapy at the end of the day may help prevent this), and blurred vision. You must be especially careful if you have an eye condition or take any other medicines that might sensitise you to bright light, such as some antibiotics. ***NM***



HOW DOES RADIOCARBON DATING WORK?

1 High-energy cosmic rays, in the form of neutrons, strike nitrogen atoms in the upper atmosphere and convert them to the radioactive isotope of carbon, which is carbon-14 (also known as radiocarbon). This quickly oxidises to create mildly radioactive carbon dioxide. About 1.1 per cent of the carbon atoms on Earth are carbon-14.

2 Plants absorb radiocarbon, along with normal carbon dioxide, during photosynthesis and incorporate it into their tissues. Herbivores eat the plants, and carnivores eat the animals, and so the radiocarbon spreads through the food chain, eventually reaching even the deepest oceans.

3 Radiocarbon is unstable, and slowly decays back to nitrogen. The half-life of carbon-14 (the period of time after which half of a given sample will have decayed) is about 5,730 years. When a plant or animal dies, it stops absorbing new carbon, so the proportion of radiocarbon in their body gradually drops due to this radioactive decay.

4 Scientists can measure the ratio of carbon-14 to the stable isotopes carbon-12 and carbon-13 with an accelerator mass spectrometer (AMS). This uses an electric field to accelerate carbon ions past a magnet that deflects their trajectory. Carbon-14 is heavier, so is deflected less. The older the sample, the less radiocarbon is still present.

5 Radiocarbon dating is believed to be accurate to within a few decades or centuries, with lower accuracy the older the sample. Dating anything older than 50,000 years is very difficult since so little radiocarbon remains after that long, but some measurements of samples up to 75,000 years old have been made.

6 In the 1950s and 1960s, nuclear weapons tests briefly doubled the levels of radiocarbon in the atmosphere and radiocarbon dating needs to account for this to remain accurate. Conversely, burning fossil fuels since 1900 has steadily lowered the amount of radiocarbon, because coal, oil and gas are all formed from plants and animals that died millions of years ago and so have essentially no radiocarbon left. ***LV***

MARK BRADY, MANCHESTER

WHAT IS BIPHASIC SLEEP?

Biphasic sleep refers to that which is taken in two phases within a 24-hour period. Examples of biphasic sleep include taking a nap during the day before sleeping again at night. Another example is of waking during the night for a period before falling asleep again.

In certain circumstances, biphasic sleep can offer advantages. For example, naps may be particularly beneficial for young children as they can support learning and development. Naps may also be useful for those who live in hot locations and might struggle to function during the midday heat. Napping more generally can increase our alertness and functioning, support the immune system and mental wellbeing and reduce stress. Nonetheless, naps are not appreciated by everyone as they can sometimes lead to sleep inertia (a groggy state experienced upon waking). They can also make it more difficult to fall asleep at night, so are best avoided in those reporting insomnia.

When it comes to waking during the night, the historian Arthur Roger Ekirch discovered that before the Industrial Revolution it was standard to have two sleeps (perhaps going to bed at 9pm or 10pm and waking after midnight for an hour or two; and then falling back to sleep until the morning). This too offered certain advantages as it was possible to visit the toilet and attend to tasks during the night such as stoking the fire and brewing ale. ***AG***

ADRIAN FLINT, VIA EMAIL

WHAT IS THE MAGNUS EFFECT?

When David Beckham curled a free kick into the goal against Greece to take England into the quarter-finals in the 2001 World Cup, he was exploiting the Magnus effect. A ball that is kicked head-on travels with the air flowing past it symmetrically in all directions. Friction with the surface of the ball causes the airflow to initially follow the contour of the ball before forming a turbulent wake that trails behind. The interactions of this wake with the surrounding air are extremely complex but they form a significant part of the overall aerodynamic drag on the ball. This interaction changes when the ball is initially kicked off-centre, sending it spinning on its own axis as it travels. The air flowing past the side of the ball rotating towards the direction of travel has a higher relative speed than the air over the opposite side. This deflects the ball's wake sideways, in the direction of the spin, which creates a reaction force in the opposite direction. This means that a ball kicked at the right of its centre will spin anti-clockwise and be deflected to the left. This deflection is called the Magnus effect, after the 19th-Century German physicist Heinrich Gustav Magnus.

Although the spin of the ball slows down as it travels, due to friction with the air, this is much less significant than the aerodynamic drag that causes the ball to lose forward speed, so the Magnus effect stays fairly constant even as the ball slows down. This causes the curvature to increase noticeably towards the end of the ball's trajectory and the effect is even more pronounced with very light balls. Table tennis provides the most extreme demonstrations of this with very dramatic deflections achieved by experienced players. ***LV***

QUESTION OF THE MONTH

PETER JACKSON, CORNWALL

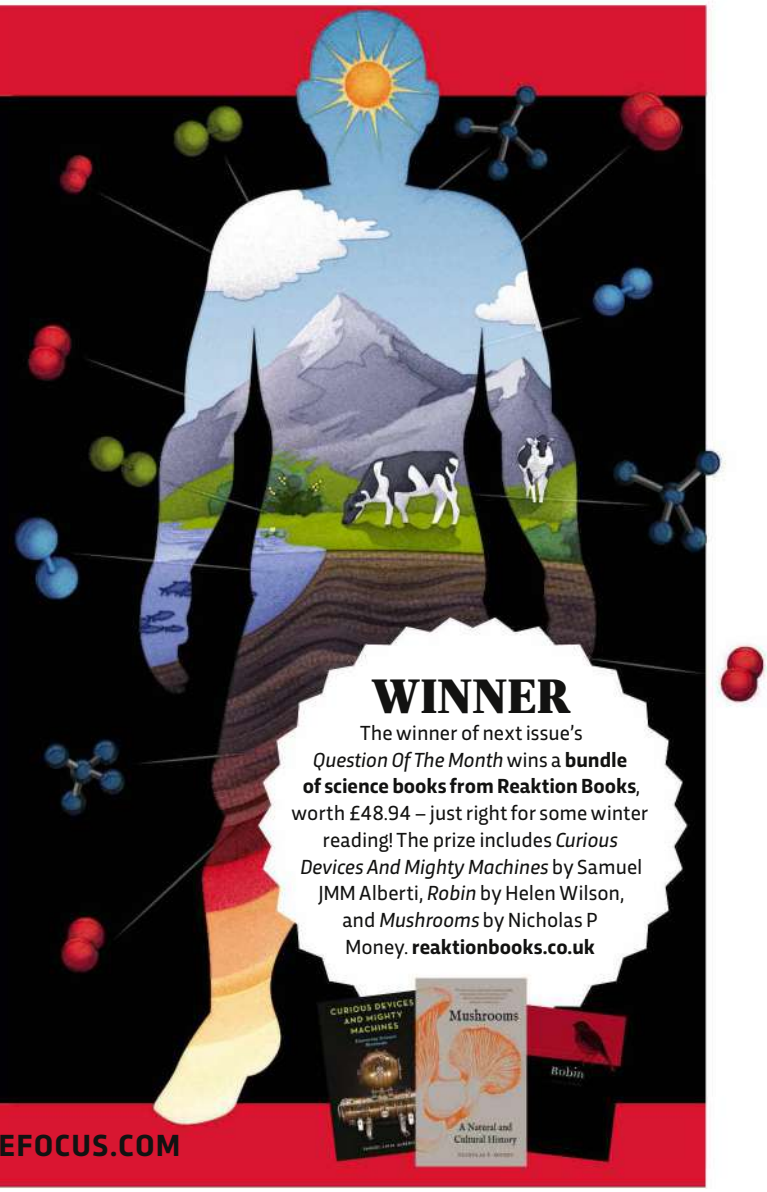
WHERE WERE THE ATOMS I AM MADE OF 100, 1,000, 1,000,000 YEARS AGO?

Four elements account for 96 per cent of your mass: oxygen, carbon, hydrogen and nitrogen. Oxygen makes up over 61 per cent of your mass, compared with hydrogen at just 10 per cent, but hydrogen is a much lighter element, so around 63 per cent of your atoms are hydrogen atoms, 24 per cent oxygen and 12 per cent carbon.

Most of your hydrogen atoms come from the water you drink, and if this is tap water from a reservoir, then 100 years ago these atoms could have been in any of the world's oceans. Groundwater aquifers exchange water more slowly though, over timescales of several thousand years. So even 1,000 years ago, some of the hydrogen in your body may have been in the groundwater beneath your feet.

Your oxygen atoms got into your body from the air you breathe. Gases in the atmosphere are churned in a chaotic way by the weather, but it's safe to assume that any given oxygen atom could have been anywhere in the world as recently as a few years ago.

Your carbon and nitrogen atoms come from food, and today's globalised agriculture also imports those atoms from all over the world. A million years ago is long enough that most of your atoms were evenly distributed throughout the planet's surface and atmosphere. Some of them would have been bound up in rocks, waiting to be weathered and released into the atmosphere or absorbed by plants. But around 5,000 tonnes of new material falls to Earth every year from space. So, it is a statistical certainty that a million years ago, some of the atoms destined to form you were trapped in asteroids, flying through space on trajectories that would eventually collide with Earth. ***LV***



WINNER

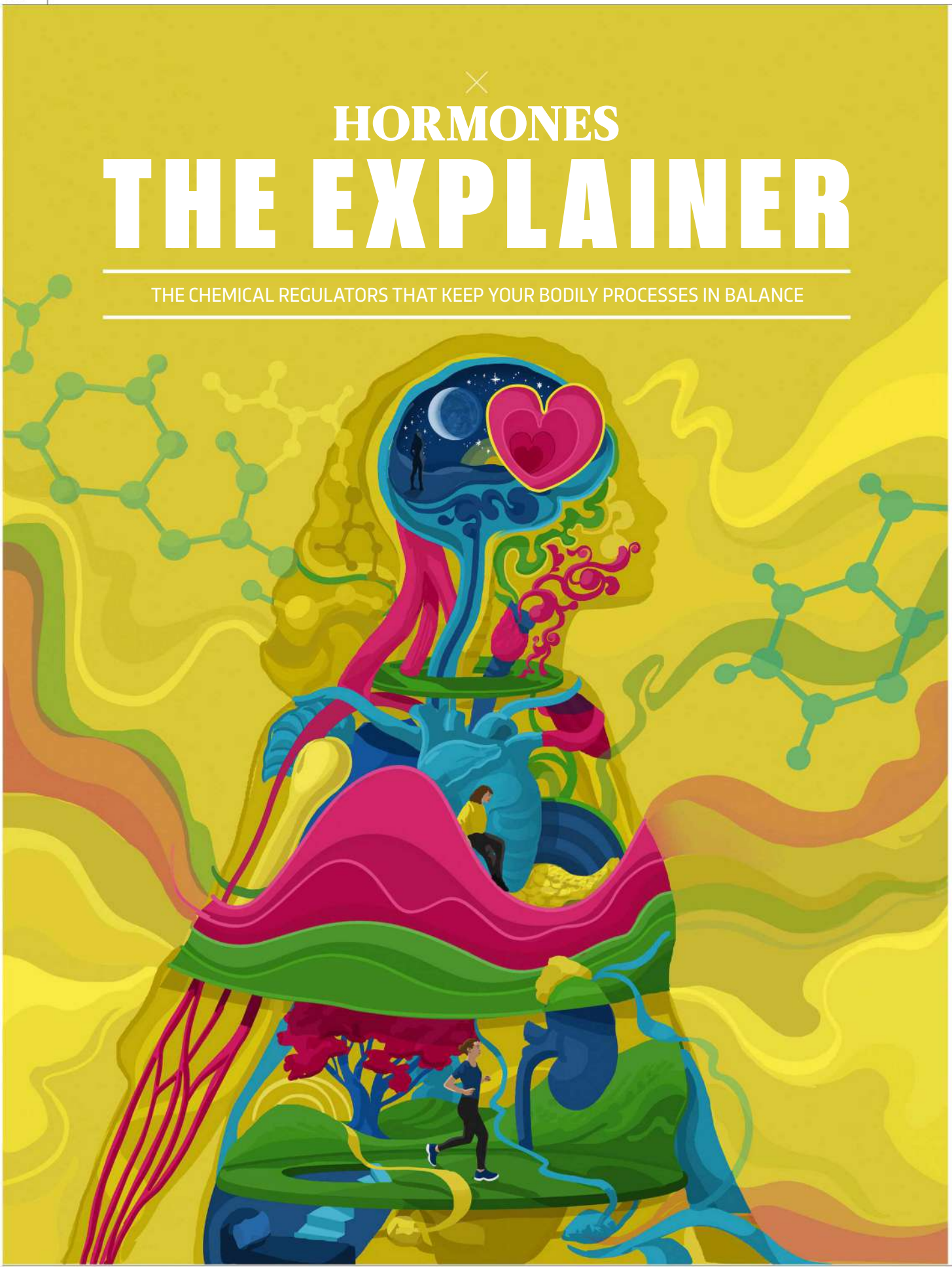
The winner of next issue's *Question Of The Month* wins a **bundle of science books from Reaktion Books**, worth £48.94 – just right for some winter reading! The prize includes *Curious Devices And Mighty Machines* by Samuel JMM Alberti, *Robin* by Helen Wilson, and *Mushrooms* by Nicholas P Money. **reaktionbooks.co.uk**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

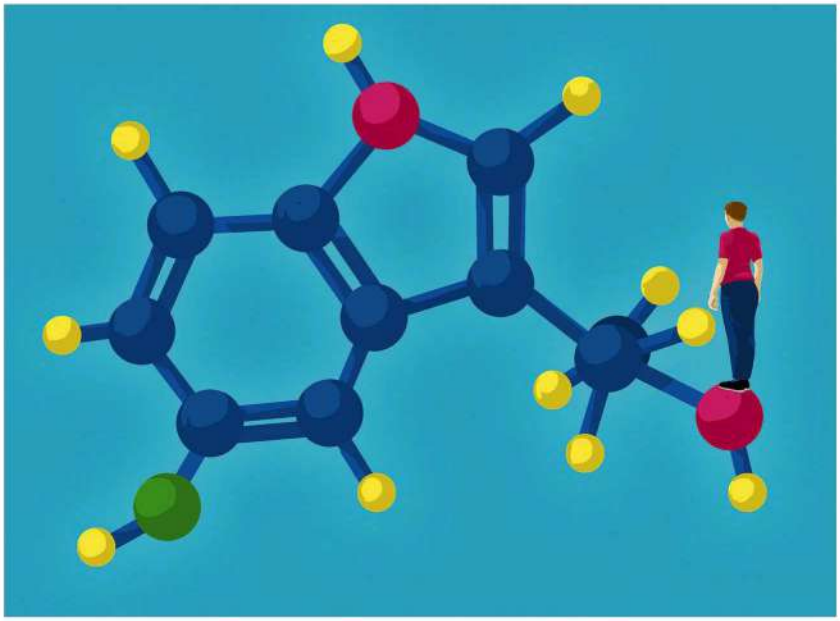
GETTY IMAGES X2 ILLUSTRATION: DANIEL BRIGHT

HORMONES
THE EXPLAINER

THE CHEMICAL REGULATORS THAT KEEP YOUR BODILY PROCESSES IN BALANCE



ILLUSTRATIONS: SAM FALCONER



What are hormones?

Hormones are chemical messengers that travel throughout the body, telling our cells and organs what to do. They regulate nearly all bodily processes and affect every aspect of our daily lives, influencing how we feel, what we look like, and how we act, whether that's hungry, hairy or happy.

Crucially, hormones are responsible for maintaining the body's delicate internal balance, which is required for optimal health. But sometimes, hormones become imbalanced or lose their ability to function effectively. This can cause a number of serious negative impacts on our health.

In other words, hormones are of great importance to every one of us, so keeping them regulated and in balance is vital, because they affect us when they work, but they can have drastic impacts on us when they don't.

What do hormones do?

Hormones provide an internal communication system between different parts of the body. The majority of hormones are produced and released by endocrine glands, which monitor and maintain the body's internal environment – a process known as homeostasis. When imbalances in the body are detected, these glands release hormones that travel in the bloodstream carrying information to tell other glands or organs what to do to bring the body back into balance.

There are more than 200 hormones in the body, each with its own unique function. For example, after you eat a sweet treat, your blood sugar levels rise. This is detected by the pancreas, which responds by releasing the hormone insulin to stimulate muscle and fat cells to increase the absorption of glucose (sugar) from the bloodstream. Hormones also communicate with other glands, telling them to increase or decrease the release of certain hormones.

We often associate hormones with things like puberty or periods, but they actually play a major role in nearly all bodily processes. You might not realise it, but under the surface, hormones are continuously working to maintain nearly every aspect of your health.

This complex network of glands, hormones and organs is what's known as the endocrine system.

"Hormones regulate nearly every aspect of our daily lives, influencing how we feel, what we look like, and how we act, whether that's hungry, hairy or happy"

HORMONES: NOT JUST FOR PUBERTY...

1. OXYTOCIN
Oxytocin is produced by the hypothalamus in the brain and is secreted into the bloodstream via the pituitary gland. It's responsible for facilitating childbirth, stimulating lactation for breastfeeding, and promoting human bonding.

2. SOMATOTROPIN
Also known as the growth hormone, somatotropin is produced by the pituitary gland. It supports growth and development, and regulates normal body structure, metabolism and blood sugar.

3. MELATONIN
Melatonin is produced by the pineal gland in the brain and is responsible for regulating the sleep-wake cycle, by stimulating feelings of sleepiness.

4. THYROXINE
Thyroxine is produced in the thyroid gland and plays a role in regulating metabolism, digestion, muscle and heart function, brain development and bone health.

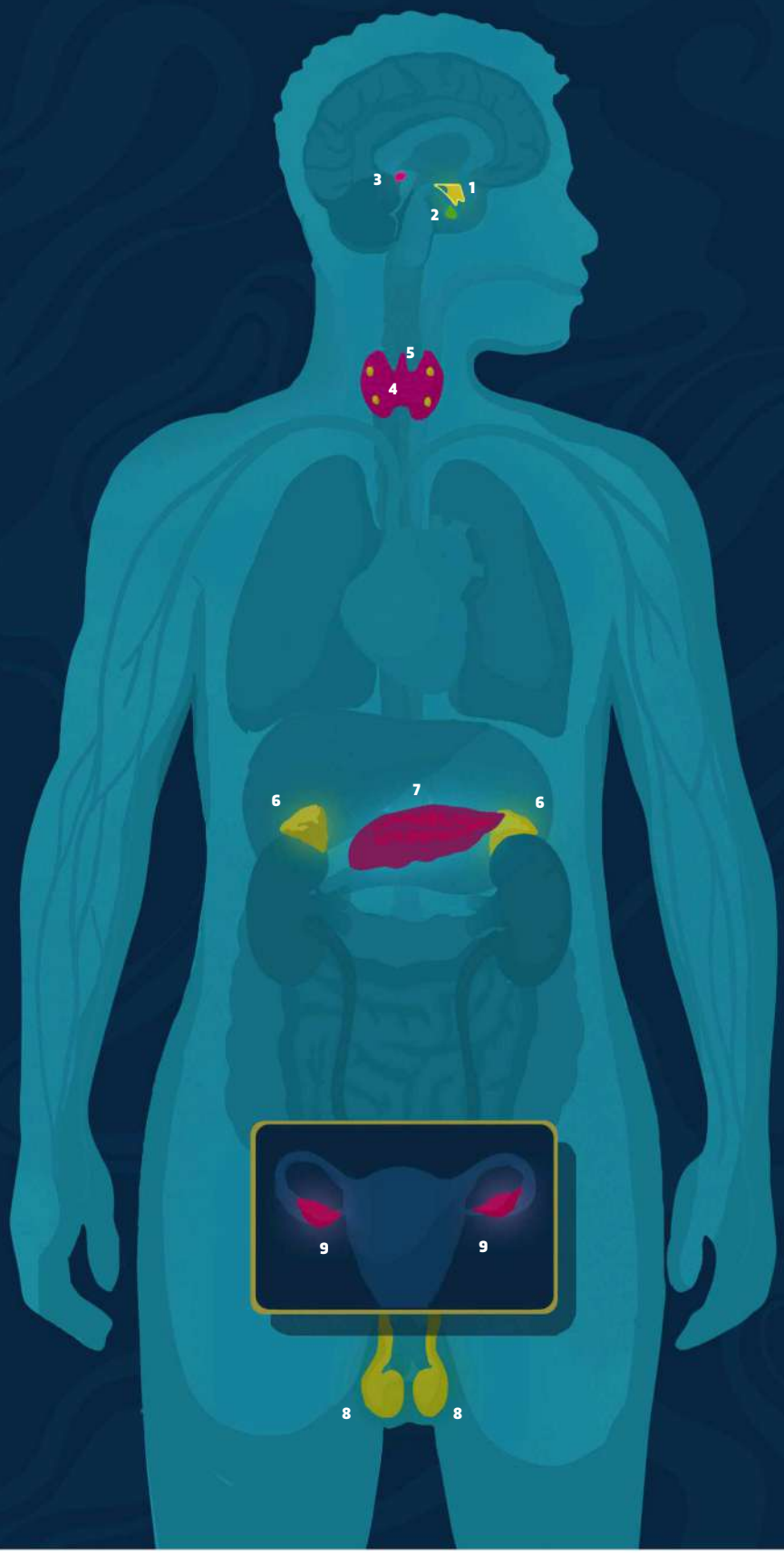
5. PARATHYROID HORMONE
The parathyroid hormone is produced in the parathyroid gland in the neck (behind the thyroid gland) and helps regulate calcium levels in the body. This is particularly important for nervous system function and muscle and bone strength.

6. ADRENALINE
Adrenaline is released from the adrenal glands, which are situated on top of the kidneys. It helps prepare the body for the effort of fleeing or defending itself, in response to stress or danger.

7. INSULIN
Insulin is produced by the pancreas. It's responsible for regulating blood sugar levels and the availability of glucose for cells to use as energy.

8. TESTOSTERONE
In men, testosterone is produced by the testes. It plays a key role in sperm production, sex drive and the development of male physical characteristics. It also regulates bone mass, fat distribution and muscle strength.

9. OESTROGEN
In women, oestrogen is produced by the ovaries. It's responsible for the development of female physical characteristics and regulating the menstrual cycle, fertility and bone strength. Oestrogen also affects the function of other parts of the body, including the brain, heart and muscles.



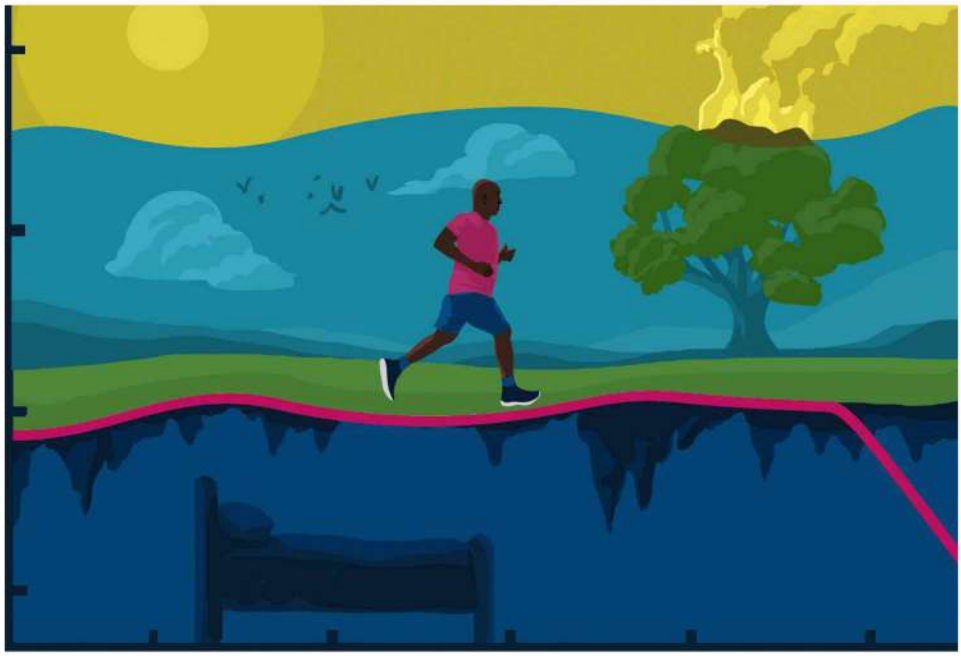
ILLUSTRATIONS: SAM FALCONER

"Typically, endocrine disorders cause abnormally high or low levels of hormones. They can also affect the body's ability to respond effectively to certain hormones"

How do hormones trigger changes in the body?

When a hormone is released from a gland, it travels in the bloodstream through the body in search of its target. Organs, tissues and other glands in the body have receptor sites that hormones must bind to in order to deliver their message and cause an effect. But because every hormone has its own unique shape, they are highly targeted and can only act on the parts of the body that have a receptor site with the corresponding shape. This mode of action can be likened to a lock and key mechanism – if the key doesn't fit the lock, then nothing will happen.

When a hormone binds to its target, it sets off a cascade of other signalling pathways to create a change in the body. Once the desired effect has taken place, this signal is fed back to the glands to suppress any further hormone release. This is what's known as a feedback loop and, when it's functioning correctly, it allows the endocrine system to ensure the conditions in your body remain in balance.



What happens when hormones don't function properly?

Hormones are essential for our survival and support the everyday function of many important bodily processes. But sometimes, parts of the endocrine system don't behave as they should, resulting in a type of medical condition called an endocrine disorder.

Typically, endocrine disorders cause abnormally high or low levels of hormones. They can also affect the body's ability to respond effectively to certain hormones. When this happens, our delicate internal balance becomes disrupted, and our health suffers. Think of it like a recipe for a cake – if you add too much or too little of any one ingredient, the final product is affected.

For example, hypothyroidism is an endocrine disorder in which the thyroid gland doesn't produce enough thyroxine. This causes a range of symptoms including fatigue, constipation, weight gain, depression, and muscle weakness. Gigantism is another endocrine disorder, but in this instance the pituitary gland produces too much growth hormone (somatotropin) in children or adolescents, causing them to grow abnormally tall.

Endocrine disorders can arise for several reasons, such as a genetic disorder, problems with the endocrine feedback system, injury to an endocrine gland, infections, or a tumour on an endocrine gland. Most hormonal conditions can't be cured, but, thankfully, they can be managed effectively with medication.

How can you tell if you have a hormone imbalance?

Some hormones fluctuate naturally as you age, or because they're part of a cycle, such as the menstrual cycle. But for others, even the slightest increase or decrease can cause major changes and impact your health.

Some of the most common signs of hormone imbalances are related to your metabolism (the chemical reactions that convert food into energy), including changes to your heartbeat, weight, energy levels, bowel movements, skin and mood.

Other imbalances are related to sex hormones, which can cause a loss of libido, loss or excessive growth of body hair, infertility, menstrual cycle and vaginal changes, and erectile dysfunction. But all of these symptoms can also be signs of other medical conditions, making it difficult to tell if you have a hormone imbalance without the help of a professional. If you experience any unusual changes in your body, always seek medical advice.

"Sleep deprivation increases levels of the stress hormone cortisol and decreases levels of the appetite-suppressing hormone leptin"

HOLLY MCHUGH

Holly is a freelance health writer with a BSc in biological sciences. She specialises in writing about hormones, nutrition, women's health, human anatomy and physiology.

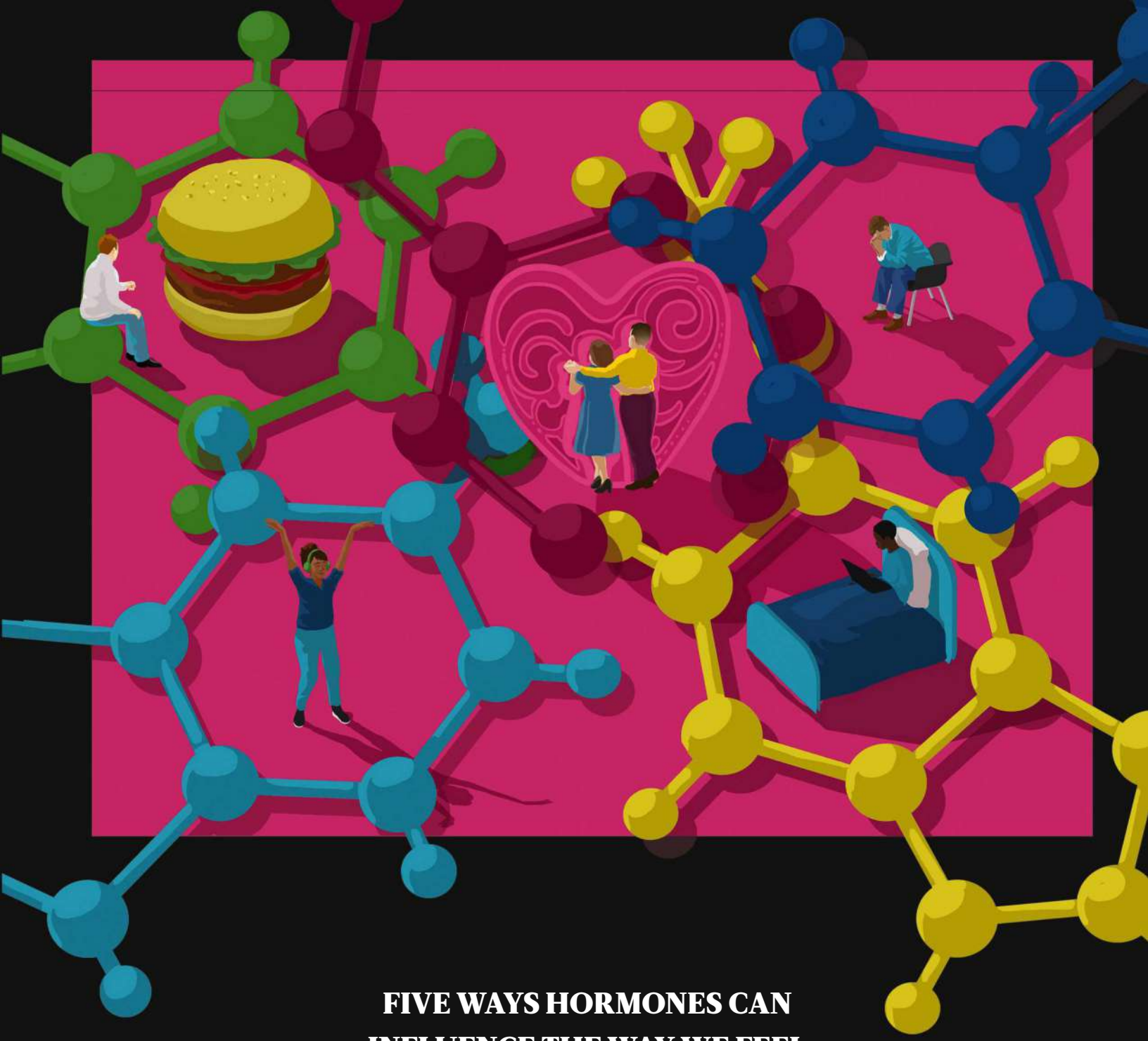
How do you keep your hormones balanced?

While hormone imbalances are sometimes caused by endocrine disorders, there are other factors that influence hormone health. Eating a healthy, nutritious diet supports good gut health, and optimises the production and function of hormones and their signalling pathways. Hormones love healthy fats, fibre and protein, but they aren't so fond of sugar, processed foods, or alcohol.

Alongside a healthy diet, regular exercise also helps keep hormones in check. This is because physical activity increases blood flow and hormone receptor sensitivity, allowing hormones to deliver their messages more effectively.

Sleep is also important for regulating hormone levels. Not getting enough shut-eye at night can upset the balance of multiple hormones. For example, sleep deprivation increases levels of the stress hormone cortisol and decreases levels of the appetite-suppressing hormone leptin. As a result, you might wake up the next day feeling unusually stressed and hungry.

Stress is another factor that may harm your hormones. Generally, when you experience a stressful situation, your body releases stress hormones like cortisol and adrenaline, which initiate a cascade of other effects in the body. Once the stressor has passed, the endocrine system's feedback mechanism suppresses the production of further hormones. However, long-term stress prevents this from happening, meaning your hormone levels aren't able to return to normal.



FIVE WAYS HORMONES CAN INFLUENCE THE WAY WE FEEL

Mood

Serotonin and dopamine are two key players involved in regulating our emotions. These are often referred to as 'happy hormones' as they promote feelings of pleasure, positivity and, as the nickname suggests, happiness!

Sleep

Melatonin helps control your body's natural sleep-wake cycle. As night draws in and low light levels are detected by the eyes, melatonin production increases, telling the body it's time to go to sleep.

Hunger

Ghrelin is an appetite-stimulating hormone, mainly produced by the stomach. When you haven't eaten in a while and your stomach is empty, ghrelin secretion increases. This sends a signal to your brain to tell you that you're hungry.

Stress

Cortisol is released by the adrenal glands in response to stress. It helps the body prepare for 'fight-or-flight' by making glucose and other nutrients more available, while suppressing non-essential bodily processes like digestion.

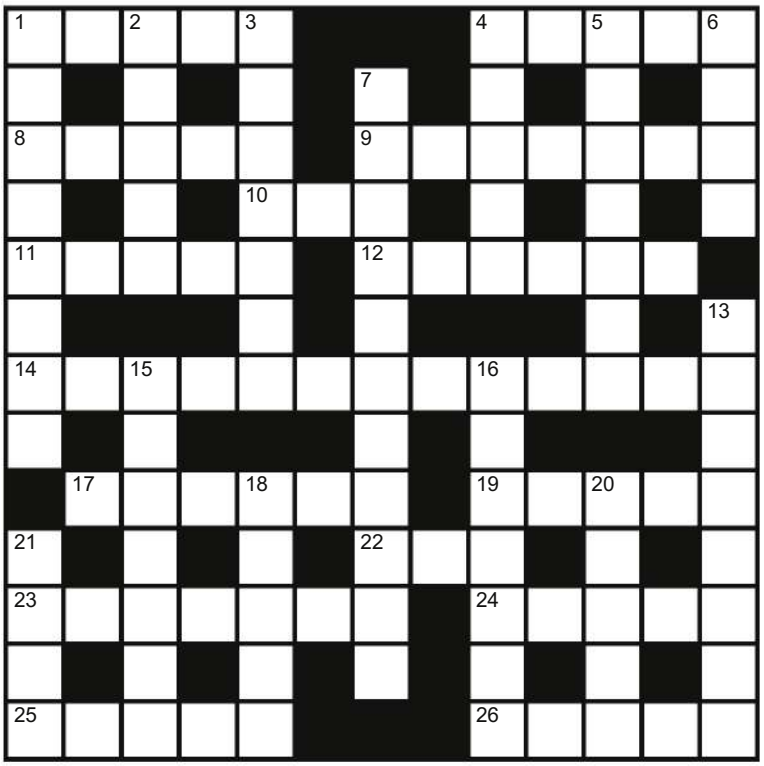
Love

Oxytocin is often referred to as the 'love hormone' because it plays a role in romantic attachment. Levels increase during physical intimacy, such as hugging and sex. It also promotes parent-child bonding and feelings of trust and empathy.

ILLUSTRATIONS: SAM FALCONER

CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Painter encountered having no trouble (5)
4 Climb aboard to be friendly (3,2)
8 British Bake-off initiated food (5)
9 Bird causes two types of fight (7)
10 Allow to hire out (3)
12 I can't be agitated about nothing in director's call (6)
14 Clairvoyant giving a lot of money to cashier (7-6)
17 Making holes is dull (6)
19 Approximately translated into Latin (5)
22 A woman's revealed inside (3)
23 Pet, male, has its own language (7)
24 Heard critical appraisal as form of entertainment (5)
25 Herds meandering a bit (5)
26 Principle of reversibility? (5)

DOWN

1 Design strongbox to remove risk (4,4)
2 Why one has to knock audibly for prize guy? (5)
3 List gold at scene (7)
4 Two types of soldier become a huge figure (5)
5 Time to mix rum with fuel in confusion (7)
6 Went out to get an amphibian (4)
7 Property seller gives gate neatest treatment (6,5)
13 Badly torn name's trinket (8)
15 Register around old bird (7)
16 Save rook inside passage (7)
18 Lied about daughter and did nothing (5)
20 Topless yellow bird (5)
21 Performs part of the Bible (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

LOVE HURTS

Nature's most gruesome mating rituals.

ALAMY

PLUS

SPACE SCIENCE IN THE SOUTHWEST

The key role that Cornwall's Goonhilly Earth Station has played in the Artemis mission.

CRISPR EXPLAINED

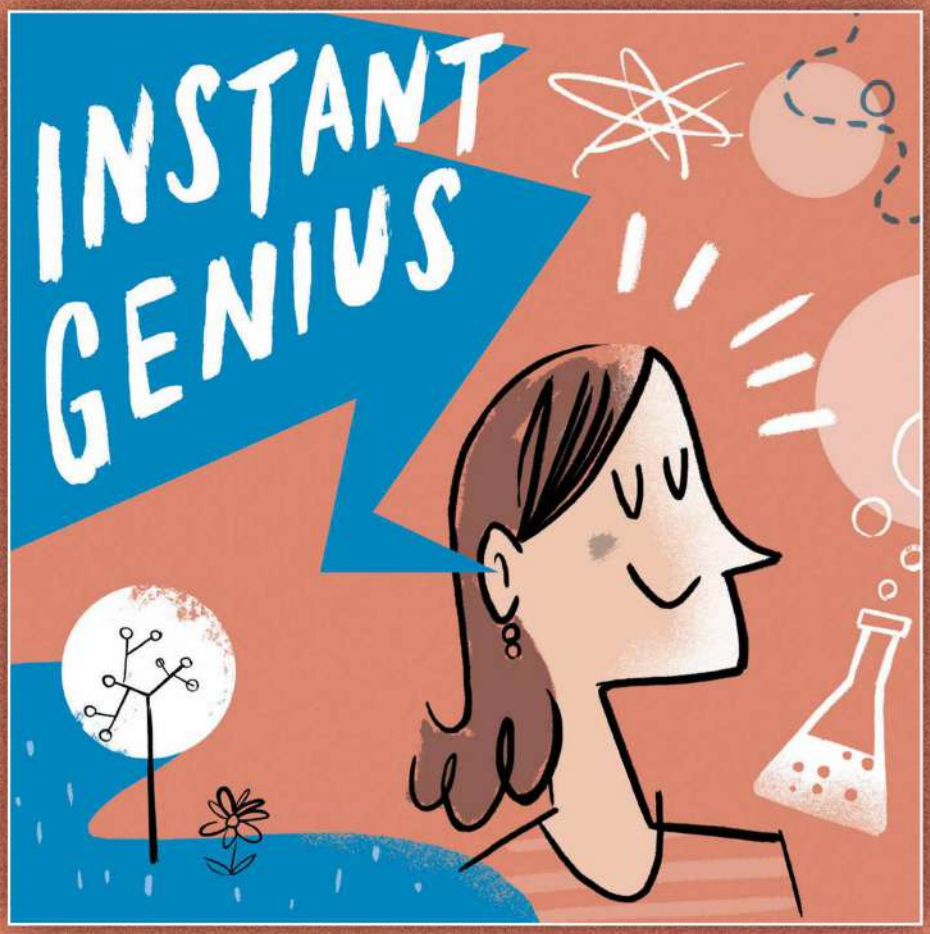
How the technique can be used for gene-editing.

ON SALE 20 JAN

SF

DON'T JUST READ THIS MAGAZINE... LISTEN TO IT TOO

Discover the weekly podcast from the team behind *BBC Science Focus*, available on Acast, Spotify, Apple Podcasts and all other podcast platforms
sciencefocus.com/instant-genius-podcast



FEATURING

SEASHELLS
with ***Dr Helen Scales***

BEE COGNITION
with ***Prof Lars Chittka***

LIFE ON MARS
with ***Lewis Dartnell***

ARTEMIS
with ***Libby Jackson***

POPCORN SCIENCE

Could we make robotic companions for kids?

January sees the release of *M3GAN*, a movie about a doll with artificial intelligence and killer dance moves

by **STEPHEN KELLY**

New horror movie *M3GAN* is essentially Chucky meets the Terminator. Its titular star is posited as the future of mass-market robots: a lifelike doll that has been programmed to be a child's best friend. It can listen, it can learn, it can dance (trust me, watch the trailer, it can *dance*) and it can also, in what is surely a big design flaw, kill. Not ideal. Deadly robots are nothing new, of course, but how feasible is the idea that a non-homicidal version of M3GAN could appear on shop shelves anytime soon?

To answer that question, we must first examine what M3GAN is; an apparent marvel of artificial intelligence (AI). "An autonomous robot does think for itself, but the scope of its actions are very limited," says Prof Peter Bentley, a computer scientist based at University College London and a regular contributor to *BBC Science Focus*. "More often than not, even the most advanced AIs are just big encyclopedias of our nonsense. They're amazing at what they can do, but there's no consciousness there. There's no understanding. There's certainly no emotion. We're very far away from anything remotely close to M3GAN."

And that, according to Bentley, also includes the idea of an AI capable of autonomous violence. "How do you tell an AI never to kill, except when we're at war?" he asks. "What if a man is holding a gun to a child's head? Should the AI shoot? What if it's a toy gun and the man is the child's father and the robot blows his head off? Building in morality and experience of the world is not something we've got the hang of." Indeed, the biggest danger to us is not 'evil' AI, he says, "but that we believe AI is better than it actually is. Just look at self-driving cars."

But M3GAN is not only a fantastical vision of artificial intelligence, she is also a genius feat of robotics. "With current humanoid robots, you're lucky if they don't fall over most of the time," says Bentley. "We can't make a robot as complex as the human body. And even if we could, we don't have a power source that would work. There are a lot of actuators to think about: all the different joints, movements and muscles we've got." In reality, says Bentley, the robot would either require an "enormous battery backpack" or would have to be plugged into a wall permanently.

As for M3GAN's souped-up TikTok dance moves, Bentley doubts that robots could ever achieve such sass. "In robotics, we talk about degrees of freedom [joints] and a robot arm might not have that many," he says. "It might just have an elbow, a wrist, some at the hands. Maybe four or six degrees of freedom. But that dance requires a level of precision that is currently not possible." This is why robots are famous for their jerky dancing. "Robots don't have sufficient degrees of freedom to achieve that fluidity of movement."

Yet Bentley's main argument against a doll like M3GAN has more to do with business than technology. He points out that recent advances in the field of AI have been driven by companies such as Google and Meta (Facebook), because there is a "clear business case" for an AI that can recognise cars or faces or fingerprints.

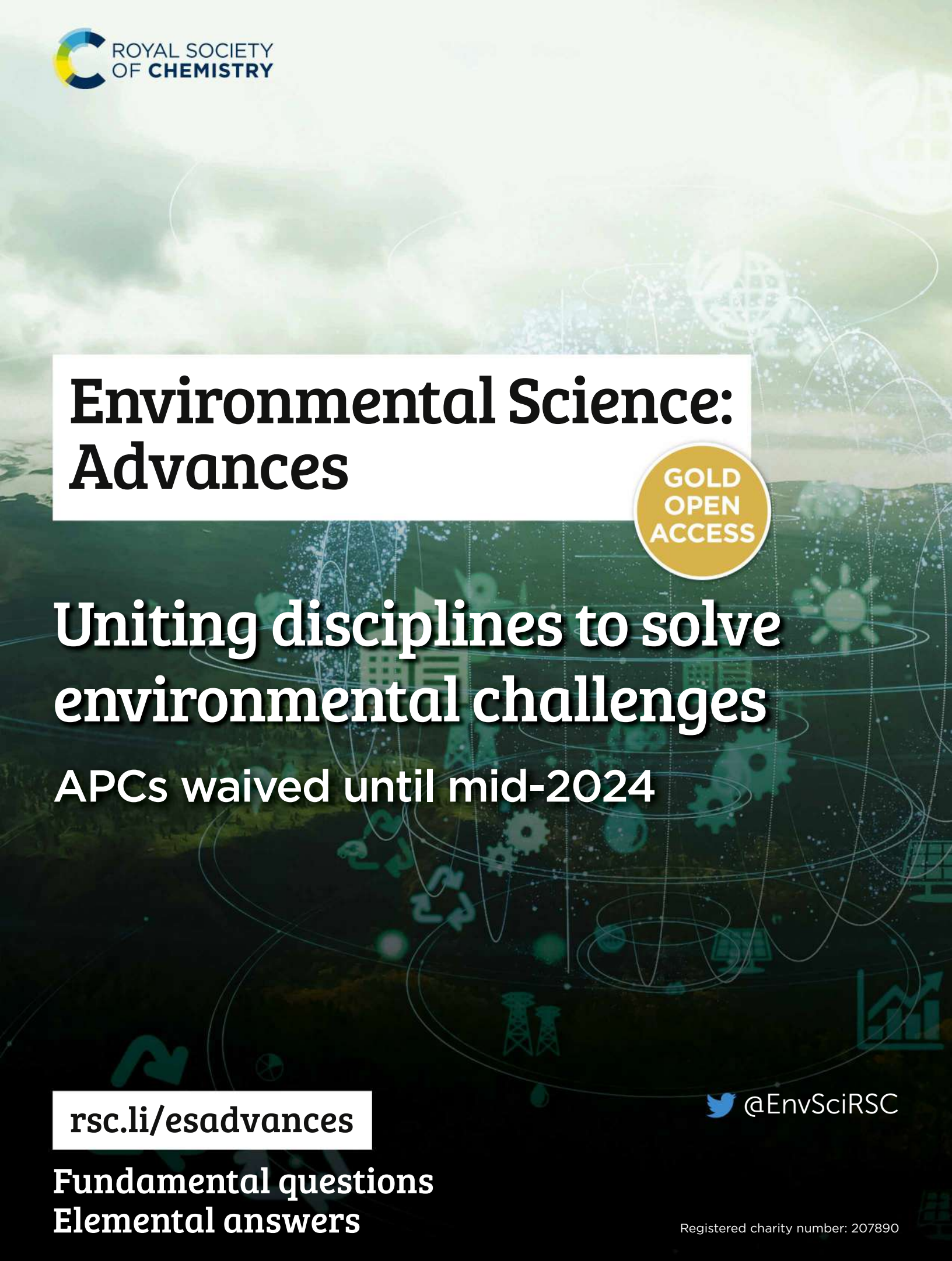
"But to develop a robot as sophisticated as M3GAN would cost billions, maybe trillions, of dollars," he says. "Is there a good business case for a freaky little humanoid robot that might kill us? It would be way more complex than your autonomous family car and therefore the price tag is going to be equal, if not more [than a self-driving car]. Ultimately, the best example of a humanoid child-shaped intelligent friend for your child is another child." **SF**

VERDICT

Thank goodness, creepy AI robot dolls will not be appearing in any toy shops. For now...

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATIONS: ADAM GALE MAIN ILLUSTRATION: DANIEL CRESPO


ROYAL SOCIETY
OF CHEMISTRY
Environmental Science: Advances
GOLD
OPEN
ACCESS
Uniting disciplines to solve environmental challenges
APCs waived until mid-2024
rsc.li/esadvances
@EnvSciRSC
Fundamental questions
Elemental answers
Registered charity number: 207890

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Will you make that promise to generations to come? Please, leave a gift in your Will to the Stroke Association.

Find out how by calling 020 7566 1505
or email legacy@stroke.org.uk
or visit stroke.org.uk/legacy

Rebuilding lives after stroke

The Stroke Association is registered as a charity in England and Wales (No 211015) and in Scotland (SC037789).
Also registered in the Isle of Man (No. 945) and Jersey (NPO 369), and operating as a charity in Northern Ireland.

Stroke Association